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COMPARISON OF DOMESTIC, HYBRID AND WILD STRAINS OF BROOK TROUT IN A POND FISHERY[1]

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ABSTRACT

The survival and harvest of stocked fall fingerling brook trout of domestic, hybrid and wild strains were compared in a pond where the fishery was managed by regulations that permitted the use of worms as bait and allowed a daily creel of 10 trout of any size. The performance of the hybrid and wild strains was generally superior to that of the domestic strain. It was concluded that allowing the use of artificial lures only should decrease hooking mortality among sub-legal fish and provide an increased harvest of older and larger trout, as well as additional sport through the catch and release of sub-legal fish.

The purpose of this study was to compare the survival and harvest of stocked fall fingerling brook trout (*Salvelinus fontinalis*) of domestic, hybrid and wild strains in a pond where the fishery was managed by regulations that permitted the use of worms as bait and allowed daily creel of 10 trout of any size. It was conducted in Black Pond near Paul Smiths in Franklin County, New York. The work was begun in 1967 and was terminated on July 30, 1970 when the abundance of yellow perch necessitated reclamation of the pond.

MATERIALS AND METHODS

The study area, the fish used and the manner in which the data were collected are described separately.

[1]A contribution of New York Federal Aid in Fish and Wildlife Restoration Project F-22-R. Bruce White, Wallace Gay, William White and the late Erwin Annis, all of the Department of Environmental Conservation, helped with various aspects of the study. Dr. Dwight Webster of Cornell University supplied eggs of the Honnedaga strain brook trout that were obtained through the courtesy of the Adirondack League Club. William Flick of Cornell University provided eggs for hybrid strain brook trout. The manuscript was reviewed by Dr. Paul Neth of the Department of Environmental Conservation and Dr. Webster. Black Pond was open to fishing through the cooperation of Paul Smith's College and the St. Regis Presbyterian Church, Paul Smiths, N.Y.

Study Area

Black Pond has a surface area of 30.8 hectares (76 acres), a maximum depth of 12.8 meters (42 feet) and a mean depth of 6.0 meters (20 feet). It supports brook trout throughout the year. Although located on private land it was open to public fishing with roadside access. Black Pond had been managed for brook trout prior to a pre-study reclamation with rotenone in August 1967. However, despite a barrier dam at its outlet, yellow perch (*Perca flavescens*), pearl dace (*Semotilus margarita*) and golden shiner (*Notemigonus crysoleucas*) became reestablished in the pond early in the study. Also, largemouth bass (*Micropterus salmoides*), brown bullhead (*Ictalurus nebulosus*), pumpkinseed (*Lepomis gibbosus*), creek chub (*Semotilus atromaculatus*) and white sucker (*Catastomus commersoni*) entered the pond during construction of a new barrier dam in 1969.

Study Fish

The brook trout used in this study comprised 2,000 each of domestic, hybrid and wild strain fish of each of the 1967 and 1968 year classes. They were stocked as fall fingerlings at a rate of 195 per hectare (79 per acre). In this paper the term "strain" is used to denote brook trout of different parentage, a usage that has been discussed by Flick and Webster (1964) and Mason et al. (1967).

The domestic brook trout were of the Crown Point (New York) strain which had been maintained at the Department's fish hatchery at Crown Point for about 15 years. This strain has typical domestic characteristics including fast growth, early maturity and a short life span. It originated from the Hackettstown (New Jersey) domestic strain via the Department's fish hatchery at Randolph. The Hackettstown strain is over 100 years old.

The hybrid strain brook trout were obtained by fertilizing eggs from domestic strain fish with milt from Assinica strain fish. The brood stock used were in private ponds in Franklin County, New York. The domestic strain is not known as it was one of two New York domestic strains in the same pond. Assinica strain brook trout are native to Assinica Lake and the Broadback River in the James Bay drainage of Quebec where they live for 8 or more years and reach weights of 4.5 to 5.4 kilograms (10 to 12 pounds) as reported by Flick (1971). Brood stocks of these fish have been developed and maintained in private waters in New York from eggs acquired in 1961. Most Assinica strain brook trout do not mature until age III + in New York waters (Flick, 1971).

Eggs of wild strain brook trout were obtained from fish native to Honnedaga Lake in Herkimer County, New York. As reported by Vincent (1960), these fish are long-lived and slow-maturing, individuals of 0.9 to 1.4 kilograms (2 to 3 pounds) being common in the spawning population.

Additional brook trout in Black Pond during the study included about

600 fish of a size vulnerable to netting and numerous smaller individuals, all naturally spawned and of unknown percentage, as well as 3,000 each of the domestic and hybrid strain fish of the 1969 year class that were stocked to maintain the fishery. The naturally produced fish were deleted from the study data because of their unknown geneology. Stocked fish of the 1969 year class were excluded because some of the hybrids were found to be heavily infested with the trematode parasite *Gyrodactylus elegans* and were subject to undue mortality.

All study brook trout were reared under similar conditions at the Department's fish hatchery at Warrensburg. Combinations of fin clips were used to differentiate strains and year classes. Trout of each strain were fin clipped several days prior to stocking. During fin clipping in 1967, small hybrid and wild strain fish and large domestic strain fish were rejected in an attempt to equalize the sizes for the different strains. This practice was not repeated with fish of the 1968 year class. Length data prior to stocking were obtained from samples of 100 marked fish of each strain. Entire marked lots were weighed at shipping, trucked to Black Pond and scattered from a moving boat over deep water. Fingerlings of the 1967 year class were stocked on November 6, and those of the 1968 year class on October 23.

DATA COLLECTION

Data were collected principally by angler survey and trap netting. The angler survey was based on a random stratified design which divided the fishing season into periods, mostly 2 weeks long, and treated weekdays, weekend days and holidays as different strata. Weekdays and weekend days were sampled as half-days in 1968 and 1969, and as complete days in 1970. Equal numbers of weekday mornings and afternoons were sampled in 1968. Weekday afternoons were sampled twice as often as mornings in 1969 because observations in 1968 showed that weekday pressure peaked during the afternoon. Weekend days were represented by equal numbers of morning and afternoon samples during both years. The angler survey coverage was complete for holidays and during spring trap netting in all three years and covered one-half of the remaining weekend days and one-third of the remaining weekdays. Survey personnel measured and weighed creeled trout, enumerated marks and recorded additional data such as length of fishing trips and methods of fishing. The data for catch and fishing pressure were expanded by strata.

The pond was netted for 3 weeks after ice-out in the spring and for 3 weeks at the end of the fishing season in the fall. The nets used included five 1.23-meter (4-foot) Oneida Lake trap nets of 1.27-centimeter (0.5-inch) square mesh and one frame net of 0.95-centimeter (0.375-inch) square mesh. Each net was tended daily, and all trout taken were processed for length, weight and marks. Netting mortality was negligible, and

all live trout were given a secondary mark and released at a central location in the pond. Spring yearlings were given a partial fin clip, whereas older trout were marked with serially numbered monel mandible tags. All trap-netted non-salmonid fish were destroyed.

Trout populations were inventoried seasonally by using mark and recapture data expanded by Schnabel and Bailey-Petersen formulae as presented by Ricker (1958). Confidence limits were determined for the 95 per cent level according to Ricker's formula for Schnabel estimates and the methodology of Adams (1951) for Bailey-Petersen estimates.

FINDINGS AND DISCUSSION

The findings are presented and discussed with respect to the relative success of the different strains of brook trout and their contribution to the sport fishery.

Population Estimates

Bailey-Petersen type estimates for brook trout of each strain of the 1967 and 1968 year classes (Table 1) were generally comparable, except for age II + wild strain fish in the spring of 1969 (i.e., fish of the 1967 year class) and for wild strain fish of the same age in the spring of 1970. The high Schnabel estimates for the spring reflect the small samples netted during that period.

In this study, Bailey-Petersen estimates are considered the better approximation of populations as they were derived from data obtained from trap netting, angler catches, pre-reclamation gill netting and reclamation. Any bias inherent in recapture by the same means as capture for marking was reduced to the minimum of 4 months between trap netting for marking and trap netting for recapture. Robsen and Regier (1964) stated that the product of the mark and recapture samples must exceed four times the estimate for the Bailey-Petersen estimate to be valid. This condition was met for all these estimates except that for age III + wild strain brook trout in the spring of 1970 which was based on a total of 12 such fish that were actually handled during and subsequent to marking in 1970.

Bailey-Petersen estimates for spring yearling populations were based on angler catches from April to August in 1968 and 1969. After August the partial fin clips had regenerated to such a degree that identification of marks was not always possible. Hatch and Webster (1961) noted that brook trout less than 16.5 centimeters (6.5 inches) in total length are not completely vulnerable to trap nets of 1.90 centimeters (0.75 inch) square mesh. Data for spring yearlings from Black Pond, particularly wild strain fish, indicated that small fish may have escaped from the trap nets (Table 2). The low number of yearling wild strain brook trout marked during the spring of 1969 strongly suggests that gear selectivity favored the capture of only the larger fish in this group.

TABLE 1. POPULATION ESTIMATES DERIVED BY TWO METHODS FOR BROOK TROUT OF THREE STRAINS AND TWO AGE GROUPS STOCKED IN BLACK POND

Year	Season	Trout marked		Method of estimate			
				Bailey-Petersen		Schnabel	
		Strain	Number	Estimate	Confidence limit*	Estimate	Confidence limit*
1967 year class							
1968	Spring	Domestic	360	760	624- 960	751	687- 828
		Hybrid	527	1,223	1,075-1,387	1,014	874-1,203
		Wild	164	574	357- 937	601	419-1,063
	Fall	Domestic	8	8	8- 8	18	11- 40
		Hybrid	32	36	33- 52	54	33- 144
		Wild	73	177	140- 261	139	97- 242
1969	Spring	Domestic	4	§	. .	5	2- 10
		Hybrid	16	25	17- 58	24	15- 57
		Wild	72	113	92- 147	471	252-3,501
	Fall	Wild	17	18	17- 25	32	15- 244
1970	Spring	Wild	10	17	11- 67	19	11- 70
1968 year class							
1969	Spring	Domestic	249	398	366- 433	350	298- 424
		Hybrid	272	914	777-1,067	904	681-1,344
		Wild	35	589	175-3,500	525	175-3,500
	Fall	Domestic	7	8	7- 20	9	4- 145
		Hybrid	48	65	56- 86	69	47- 128
		Wild	142	288	256- 375	279	195- 487
1970	Spring	Domestic	3	5	2- 20	§	. .
		Hybrid	37	43	40- 55	60	43- 98
		Wild	286	272	230- 339	342	280- 441

*At 95 per cent level.
§No marked specimens recaptured.

SURVIVAL

Survival data were generally calculated by using the Bailey-Petersen method; however, the Schnabel method was used to estimate the number of age II + wild strain brook trout present in the spring of 1969. The data are plotted as percentages of preceeding inventories that have been adjusted where necessary to compensate for angler catches (Figure 1). No inferences can be drawn about the comparative survival of domestic strain and wild strain brook trout during their first winter in Black Pond, but the first winter survival of both year classes of the hybrid strain was superior to that of the other strains. Flick and Webster (1964) noted no clear difference in overwinter survival between domestic strain and wild strain brook trout but reported that wild strain fish survived better over the summer.

Greene (1951) stocked fall fingerling brook trout of a domestic strain and a New York wild strain (Cranberry Lake strain), at a ratio of 4.5:1, in Stillwater Pond where a minimum size limit of 7 inches (178 millimeters)

TABLE 2. RECORDS OF LENGTH AND WEIGHT FOR BROOK TROUT OF THREE STRAINS AND TWO AGE GROUPS STOCKED IN BLACK POND AT TIME OF STOCKING AND AS SUBSEQUENTLY SAMPLED BY ANGLING, NETTING AND RECLAMATION

Date and type of sample	Strain	Total length			Weight		
			Millimeters			Grams	
		Number of fish	Mean	Range	Number of fish	Mean	Range
1967 year class							
1967 October Stocking	Domestic	100	122 ± 16	86-157	100	20	. .
	Hybrid	100	121 ± 13	91-160	100	16	. .
	Wild	100	107 ± 11	86-132	100	12	. .
1968 Spring Netting	Domestic	372	166 ± 20	112-218	372	53 ± 21	14-114
	Hybrid	534	163 ± 19	114-216	534	44 ± 17	14-114
	Wild	172	145 ± 16	99-185	172	30 ± 12	14- 71
1968 Angling	Domestic	137	211 ± 37	140-292	119	117 ± 69	30-300
	Hybrid	416	236 ± 44	137-343	340	157 ± 93	30-455
	Wild	159	245 ± 33	160-315	142	171 ± 61	40-335
1968 Fall Netting	Domestic	9	280 ± 29	221-312	9	278 ± 83	142-392
	Hybrid	31	284 ± 30	193-353	31	248 ± 75	85-426
	Wild	73	268 ± 21	218-310	73	211 ± 54	99-326
1969 Spring Netting	Domestic	4	318 ± 23	290-345	4	408 ± 60	369-497
	Hybrid	20	334 ± 30	287-386	20	395 ± 111	241-568
	Wild	79	315 ± 27	244-358	79	320 ± 78	156-440
1969 Angling	Domestic	1	277	. .	1	265	. .
	Hybrid	17	343 ± 34	284-404	17	452 ± 146	225-825
	Wild	60	324 ± 26	267-378	60	385 ± 94	170-650
1969 Fall Netting	Wild	15	367 ± 17	328-389	15	573 ± 119	426-809
1970 Spring Netting	Wild	12	381 ± 19	340-406	12	593 ± 106	397-773
1970*	Wild	6	385 ± 15	366-396	6	628 ± 49	540-675
1968 year class							
1968 October Stocking	Domestic	100	132 ± 12	97-165	100	29	. .
	Hybrid	100	91 ± 12	66-117	100	8	. .
	Wild	100	76 ± 11	53-102	100	4	. .
1969 Spring Netting	Domestic	252	178 ± 15	122-216	252	58 ± 15	14- 99
	Hybrid	279	144 ± 12	109-196	279	26 ± 9	14- 85
	Wild	37	129 ± 11	107-155	37	17 ± 7	14- 43
1969 Angling	Domestic	152	226 ± 26	157-323	147	147 ± 63	40-500
	Hybrid	295	216 ± 29	142-305	278	120 ± 51	30-350
	Wild	140	206 ± 23	132-259	135	98 ± 34	30-195
1969 Fall Netting	Domestic	7	284 ± 20	259-310	7	236 ± 57	170-341
	Hybrid	46	261 ± 33	178-328	46	178 ± 62	57-326
	Wild	115	226 ± 21	170-282	115	102 ± 33	43-206
1970 Spring Netting	Domestic	3	325 ± 25	305-353	3	411 ± 129	326-560
	Hybrid	49	316 ± 34	218-381	49	320 ± 86	163-546
	Wild	160	279 ± 21	226-338	160	213 ± 60	78-433
1970*	Domestic	4	324 ± 49	257-366	4	382 ± 149	195-505
	Hybrid	32	324 ± 34	221-381	32	379 ± 113	150-650
	Wild	138	292 ± 25	231-366	135	259 ± 82	115-575

*Comprises trout taken by angling, netting and pond reclamation from termination of netting in the spring through July 30.

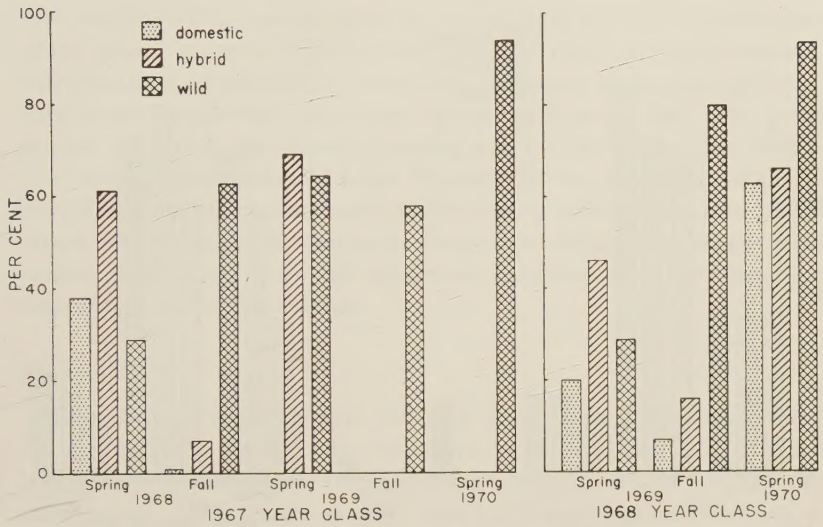

Figure 1. Percentage survival of domestic, hybrid and wild strain brook trout in Black Pond, based on the number stocked or previous population estimates adjusted to compensate for estimated angler catches.

was in effect. He suggested that survival of the wild strain was superior to that of the domestic strain during the entire time the fish were in the pond. In Black Pond, the summer and subsequent survival of wild strain brook trout was superior to that of the other strains when all forms of mortality are considered. Low initial survival may represent heavy post-stocking predation by mergansers (*Mergus* sp.). Stocking dates generally coincided with the southern migration of waterfowl, and flocks of up to 40 mergansers were observed feeding on the pond following stocking. Trout emmigration, possible during the late fall and winter of 1968 and 1969 when ice necessitated removal of the metal hardwarecloth screening over the fish barrier panel at the pond outlet, may have biased survival data. The screening was left in place on the barrier panel during most of the rest of the study. Black Pond had no known history of fish winterkill and there was no evidence of this problem during the study.

GROWTH

Size selection at the hatchery during marking of 1967-year-class fish probably affected the comparability of the growth data for them and made the data for the 1968 year class (Table 2) a more representative index of the size potential for fish of each strain as they occurred in a "normal" population (hatchery lot). Selection of smaller domestic strain individuals during marking in 1967 was reflected in the smaller size of fish of this strain and year class during subsequent netting operations when compared with domestic strain fish of the 1968 year class at the same age. Just the op-

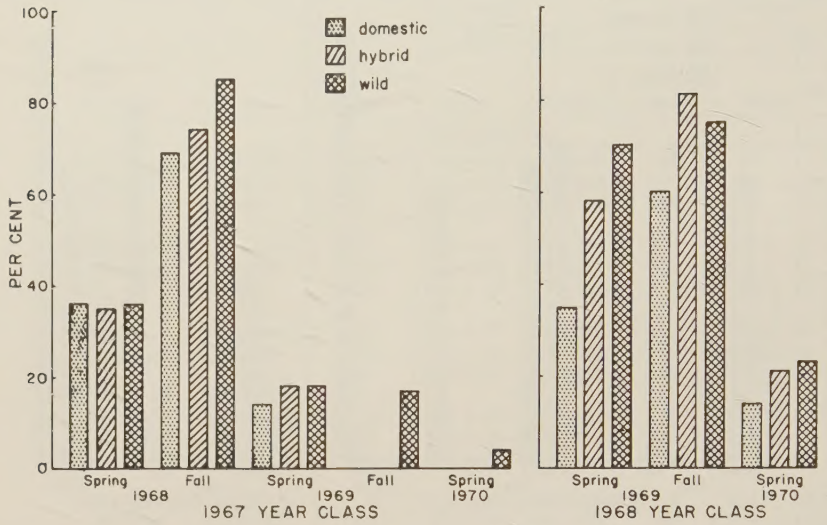

Figure 2. Percentage gain in total length for domestic, hybrid and wild strain brook trout in Black Pond, based on the corresponding average for fish sampled the previous season.

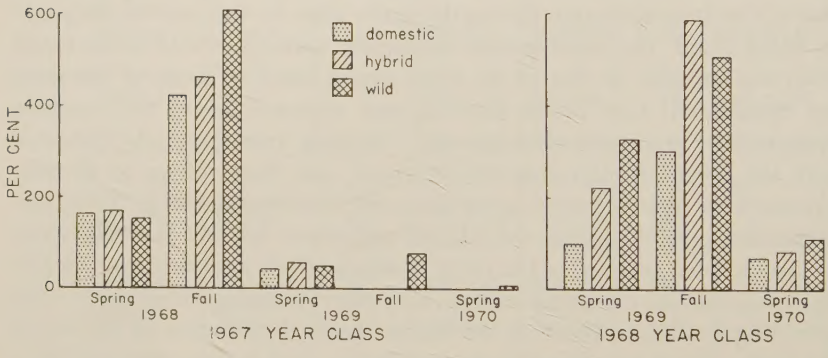

Figure 3. Percentage gain in weight for domestic, hybrid and wild strain brook trout in Black Pond, based on the corresponding average for fish sampled the previous season.

posite was the case for the hybrid and wild strains where selection of larger individuals during marking in 1967 gave these fish a size advantage over their counterparts of the 1968 year class at comparable ages. Size selection of study fish during marking at the hatchery was discontinued in 1968 to better reflect the hatchery product.

If larger brook trout are more vulnerable to angling than smaller individuals, a negative bias might be inherent in the growth profiles (Figures 2 and 3) for fish of the different strains. Consequently, an ideal profile of the growth of these fish would involve samples from a population protected

from angling. This was not possible, but the data provide some description of the growth patterns of fish of each strain. Growth in length and weight from stocking in the fall of 1968 to the following spring was greatest for wild strain brook trout and least for domestic strain fish. The greatest growth for any strain occurred among age I + hybrids of the 1968 year class during the summer of 1969. The data for the wild strain of the 1968 year class may reflect sampling bias. Selectivity of the trap nets to catch the larger fish of this strain and year class, while allowing the smaller fish to escape, would provide growth data more representative of the faster growing portion of the population.

MATURITY

Some data on maturity were collected during a second netting period in the fall of 1969. At that time an entire catch of 11 age II + wild strain brook trout were mature, compared with only 5 of 39 age I + fish of the same strain. Of a catch of eight age I + hybrid strain fish, two were mature. A single mature male was the only domestic strain fish taken during this period. A large proportion of the age 0 + domestic strain fish noted during marking of the 1968 year class were mature males. Size selection for the larger brook trout of the 1967 year class was probably responsible for the earlier maturity of wild strain fish of that year class in contrast to the 1968 year class. Webster (1961) suggested that brook trout of the Honnedaga strain may mature at age I + if they reach 254-305 millimeters (10-12 inches) in total length by the end of the second growing season. For wild strain brook trout in Black Pond (Table 2), mean length exceeded 254 millimeters for fish of the 1967 year class in the fall of 1968 but not for those of the 1968 year class in the fall of 1969.

FISHERY

Table 3 summarizes the number of angler trips and the fishing pressure on Black Pond, both observed and estimated, during the study. Most anglers fished from boats as the wooded shoreline afforded limited space

TABLE 3. ANNUAL ANGLER USE OF BLACK POND FROM OPENING OF FISHING SEASON IN 1968 THROUGH JULY 30, 1970*

Year	Data	Angler trips		Fishing pressure	
		Number	Number per hectare	Hours	Hours per hectare
1968	Observed	416	13.5	924	30.0
	Estimated	965	31.3	2,144	69.6
1969	Observed	504	16.3	1,157	37.6
	Estimated	1,115	36.2	2,560	83.1
1970	Observed	546	17.7	1,366	44.4
	Estimated	890	28.9	2,226	72.3

*Open season: April 1 - September 30.

for casting. The typical angler trolled a worm-wobbler combination or stillfished with worms.

Fishing pressure increased from year to year. In 1970 it was greater than in 1968 even though reclamation of the pond on July 30 shortened the season by two months and would have exceeded that in 1969 if it had continued through the end of September. The greatest number of angler trips (546) were observed in 1970. Peak fishing pressure coincided with higher rates of angler success during the early and late parts of the season, although anglers who knew Black Pond were very successful in taking trout near springs during the warmest part of the summer. Throughout each season most fishing occurred in the early afternoon.

Most anglers were cooperative with the creel-survey agents but appeared uninterested in the strain(s) of trout making up their catch. Their interest was rather in the number and size of the fish taken.

Angler Catch

Yearling brook trout made up nearly 89 per cent of the estimated angler catch in Black Pond (Table 4) and the majority of trout of all strains were creeled as yearlings. Each strain dominated the catch for part of the fishing season in both 1968 and 1969 (Figure 4), the order of dominance among the yearlings being the domestic strain, hybrid strain and wild strain. Brook trout of the wild strain were the only fish contributing appreciably to the fishery at age II + and the only ones at age III + . Age II + wild strain fish were dominant in the angler catches during the first part of the 1969 season. Comparison of the relative size, abundance and number caught suggests that dominance of fish of one strain and age group in the catch was related primarily to size and secondarily to abundance. Greene (1951) reported that most of the wild strain brook trout

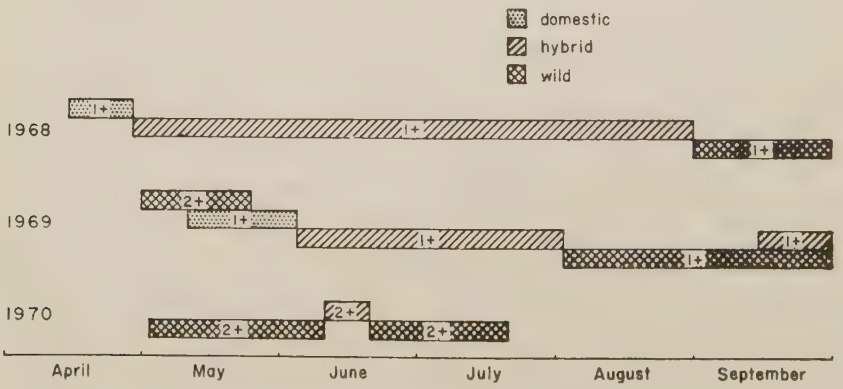

Figure 4. For age 1 + and 2 + brook trout, periods of season during which the different strains were dominant in the angler catch in Black Pond in 1968, 1969 and 1970 (overlap denotes equal harvest).

TABLE 4. OBSERVED AND ESTIMATED ANGLER CATCH OF BROOK TROUT IN BLACK POND, ACCORDING TO STRAIN AND AGE

Age	Strain									Total		
	Domestic			Hybrid			Wild					
	Observed	Estimated		Observed	Estimated		Observed	Estimated		Observed	Estimated	
		Number	Per cent*		Number	Per cent*		Number	Per cent*		Number	Per cent*
1967 year class												
I+	113	220	8.7	314	719	28.4	118	291	11.5	545	1,230	48.6
II+	0	. .	. .	17	33	1.3	43	82	3.2	60	115	4.5
III+	0	. .	. .	0	. .	. .	3	4	0.1	3	4	0.1
Sub-total	113	220	8.7	331	752	29.7	164	377	14.8	608	1,349	53.2
1968 year class												
I+	156	282	11.2	320	500	19.8	162	229	9.1	638	1,011	40.1
II+	4	4	0.1	26	37	1.5	98	128	5.1	128	169	6.7
Sub-total	160	286	11.3	346	537	21.3	260	357	14.2	766	1,180	46.8
Total												
Total	273	506	20.0	677	1,289	51.0	424	734	29.0	1,374	2,529	100.0

*All percentages based on aggregate estimated total.

caught in Stillwater Pond were creeled at age II + and suggested that this may have been because the smaller size of the wild strain fish provided for fewer legal-sized yearlings of that strain than of the domestic strain.

The composition of the estimated angler catch in Black Pond was 51, 29 and 20 per cent, respectively, for the hybrid, wild and domestic strains of brook trout (Table 4). Hybrids represented a return of about 32 per cent of the number stocked, while for wild strain and domestic strain fish the return was about 18 and 13 per cent, respectively. According to weight of trout caught, hybrid strain fish accounted for about 50 per cent, wild strain about 33 per cent and domestic strain about 17 per cent (Table 5). The yield of hybrids was 4.17 times as great as the weight of hybrids stocked. while the corresponding values for wild strain and domestic strain brook trout were 3.99 and 0.67, respectively.

Table 5. Weight Stocked and Estimated Yield For Brook Trout in Black Pond, According to Strain

Strain	Year class			Percentage of total	
	1967	1968	Total	Stocked	Yield
Domestic					
Stocked (kilograms)	41.8	60.8	102.6	55.0	
Yield					
Kilograms	25.7	42.9	68.6		16.7
Per cent*	61.5	70.6	66.9		
Hybrid					
Stocked (kilograms)	33.6	16.3	49.9	26.7	
Yield					
Kilograms	134.8	73.1	207.9		50.4
Per cent*	401.2	448.5	416.6		
Wild					
Stocked (kilograms)	25.0	9.1	34.1	18.3	
Yield					
Kilograms	83.2	52.7	135.9		32.9
Per cent*	332.8	579.1	398.5		

*Of weight stocked.

Proportional angler catches from Stillwater Pond differed between the two year classes (Greene, 1951). While domestic strain brook trout represented 58 per cent of the weighted catch for the 1948 year class, wild strain fish accounted for 56 per cent of that for the 1949 year class. Greene also reported that Cranberry Lake and its tributaries had been stocked with domestic strain brook trout for more than 50 years and that the brood stock for the 1948 year class included individuals 9 inches (229 millimeters) in total length, while for the 1949 year class the brood stock ranged from 16 to 19 inches (406 to 482 millimeters). The smaller fish of the brood stock used for the 1948 year class may have been of a mixed strain that produced progeny showing neither the vigor of first-generation hybrids nor the characteristics, i.e., longer life and superior size, of Cranberry Lake brook trout. The comparative ratios for the numerical yields of wild strain and

domestic strain brook trout from Black Pond (1.45:1) and Stillwater Pond (0.97:1) suggest that hooking mortality may have been higher among the wild strain fish in Stillwater Pond and associated with the combination of a 7-inch size limit and the allowance of the use of bait. Initial slow growth of the wild strain brook trout there would have resulted in the number of sublegal angler-caught fish returned to the water being greater for them than for the domestic strain fish and would have provided a greater chance of hooking mortality among the wild strain trout. Yields by weight for brook trout in Stillwater Pond, in proportion to the different number of fish of each strain stocked, favored the wild strain for both year classes.

Flick (1971) compared the harvest of brook trout of the same hybrid strain used in the present study with that of domestic strain and Canadian wild strain brook trout, stocked in equal numbers as fall fingerlings but not harvested until age II + . He reported that the hybrids represented about 82 per cent of the yield by weight, while the domestic strain fish accounted for 12 per cent and the Canadian wild strain fish 6 per cent. The greater return of hybrids probably resulted from delaying the harvest until the fish were age II + . On the other hand, the poor showing of the Canadian wild strain trout, compared with that of the New York wild strain fish in the present study, seems primarily to have reflected differences in the conditions of the two studies. In Black Pond, the wild strain fish were the last to dominate the angler catch and therefore had a longer time to grow larger. In the study reported by Flick, the wild strain brook trout had had less time in which to grow prior to harvest.

In the present study, for angler-caught brook trout of the 1967 year class, the wild strain fish averaged greatest in total length among the yearlings, while the hybrids averaged largest in the II + age group (Table 2). For the 1968 year class, domestic strain fish averaged largest, both as yearlings and at age II + . The largest fish recorded during the entire study was an angler-caught, age II + hybrid of the 1967 year class which measured 404 millimeters (15.9 inches) in total length and weighed 0.83 kilogram (1.82 pounds). One age III + wild strain fish handled during netting the spring of 1970 was 2 millimeters longer but weighed 0.77 kilogram (1.70 pounds).

MANAGEMENT IMPLICATIONS

A summary ranking the strains according to their performance in the fishery in Black Pond (Table 6) shows the general superiority of the hybrid and wild strains. These findings, as well as those from previous studies, indicate that regulations may be used to optimize the performance of hybrid and wild strain brook trout. Greene (1951) showed that, in Stillwater Pond under a 7-inch (178-millimeter) minimum size limit, the greatest proportions of wild strain brook trout were harvested at age II + and suggested that hooking mortality may have been higher among this strain than the

Tablf 6. Relative Performance Ranking in Fishery For Three Strains of Brook Trout Stocked in Black Pond*

Criterion	Strain		
	Domestic	Hybrid	Wild
Dominance in fishery as yearlings	3	1	2
Greatest mean total length as yearlings	3	1	2
Greatest mean weight as yearlings	1	2	3
Largest trout caught	3	1	2
Longevity	3	2	1
Yield per kilogram stocked	3	1	2
Total yield in kilograms	3	1	2
Total number harvested	3	1	2
Total			
Number	22	10	16
Average	2.75	1.25	2.00

*Figures represent averages for the two year classes as follows: 1 = highest; 2 = median; 3 = poorest.

domestic strain. A minimum size limit and hooking mortality would have had a lesser effect on the long-term survival of domestic strain fish. Previous authors have reported poor survival of domestic strain brook trout to age II + regardless of the fishing pressure (Greene, 1951; Zilliox and Pfeiffer, 1960; Hatch and Webster, 1961). Additional restrictions are suggested by the findings of Mason and Hunt (1967) who reported hooking mortalities ranging from 35 to 95 per cent among deeply-hooked rainbow trout (*Salmo gairdneri*). Such deep hooking was not common among trout taken on artificial lures in Black Pond and occurred most often with trout caught by stillfishing. Restrictions on the use of bait, allowing the use of artificial lures only, should decrease the hooking mortality among sub-legal fish. This would provide an increased harvest of older and larger trout, as well as additional sport through the catch and release of sub-legal fish.

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POPULATION CHARACTERISTICS AND MORTALITY FACTORS OF THE RED FOX IN CENTRAL NEW YORK[1]

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ABSTRACT

Red foxes were captured, tagged and released on a 10-mile-square study area in Cayuga County, New York, during a 5-year period. Carcasses of tagged and untagged foxes killed or found dead on or in the vicinity of the study area were obtained, largely through the cooperating public. These were examined to determine sex, age and cause of death. Estimates indicated that the summer populations on the area were relatively stable but probably below the carrying capacity of the range. The recorded annual harvest by fur trapping and sport hunting did not exceed 33 per cent of the summer population. However, of the red foxes taken each trapping season, the proportion of juveniles averaged 69 per cent and only 2 per cent had lived more than 4 years. This indicated a rate of turnover greater than the recorded mortality would have accounted for.

The only natural mortality factor recorded was sarcoptic mange, an ectoparasitic disease which is fatal to infested red foxes. Sarcoptic mites appear to spread through contact between animals. Such contact occurs frequently during mid-winter mating and in late spring and summer. The apparent epidemiology of mange in red foxes is discussed. It was concluded that this disease would eventually control red fox populations if harvesting by fur trapping and hunting were limited or discontinued.

An investigation of the characteristics of fox populations in New York and the factors affecting them was undertaken in 1942. The background and objectives of the work were given by Tullar and Berchielli (1980) in a paper reporting findings concerning the movement of red foxes. The present paper gives the findings that relate to population characteristics and mortality factors of the red fox (*Vulpes fulva*) in central New York. The study area and the methods used to locate, capture and tag specimens as well as to distinguish pups from adults were described by Tullar and Berchielli (1980). The data presented here were recorded chiefly during the years 1972-73 to 1976-77. They represent primarily red foxes found dead on the study area or in the vicinity and the carcasses of animals taken by hunters and trappers, although the age and sex of foxes live trapped on

[1]The authors depended heavily upon the good will and cooperation of most of the landowners in the Towns of Brutus, Cato, Conquest, Mentz, Sennett and Throop in Cayuga County. Many trappers, hunters and fur dealers in Cayuga, Onondaga, Oswego, Seneca and Wayne Counties provided information about tagged foxes at their own expense. Environmental Conservation Officers E. M. Lamphere, M. L. Mobbs, W. Hasenjager, G. K. Viele and C. M. Gay also provided support. Special thanks are due Ernest Saggese (deceased), S. Van Wie, C. Barrett, D. Stalnaker, A. Martel, H. Parish and E. Davies who live trapped and tagged foxes on the study area and also collected most of the specimens obtained from fur trappers and hunters. E. J. Parks and G. H. Teidman helped plan the study and choose the study area. J. Proud, R. Loveless (deceased) and D. Smith cooperated in providing the Howland Island Wildlife Management Area as a base of operations.

the study area were also recorded. Analysis of these data provides a useful representation of the structure of red fox populations and indicates the relative importance of the observable mortality factors.

The seasonal distribution of the specimens autopsied is summarized in Table 1 according to whether or not they had been tagged. For both groups, the largest proportion (50 and 87 per cent, respectively) was taken

TABLE 1. SEASONAL DISTRIBUTION, ACCORDING TO WHETHER OR NOT THEY HAD BEEN TAGGED, OF RED FOXES FOUND DEAD OR TAKEN BY HUNTERS AND TRAPPERS ON OR IN THE VICINITY OF THE CAYUGA STUDY AREA, 1972-73 TO 1976-77

Age	Total number	Seasonal distribution							
		Spring		Summer		Fall		Winter	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Tagged									
Juvenile	141	2	1	43	30	79	56	17	12
Adult	58	9	16	13	22	21	36	15	26
Sub-total	199	11	6	56	28	100	50	32	16
Ratio*	2.4	0.2		3.3		3.8		1.1	
Untagged									
Juvenile	737	22	3	42	6	641	87	32	4
Adult	344	6	2	16	5	297	86	25	7
Sub-total	1,081	28	3	58	5	938	87	57	5
Ratio*	2.1	3.7		2.6		2.2		1.3	
Total									
Total	1,280	39	3	114	9	1,038	81	89	7

*Juveniles per adult

in the fall indicating that those (other than project personnel) who furnished specimens were most interested in foxes during that season. Apart from the fall when by far the greatest number of specimens was obtained, the proportion of tagged foxes consistently exceeded that of untagged foxes. This suggests that, except during the trapping season, tagged foxes were the more likely to be submitted by cooperators.

Age ratios for the untagged foxes appeared to reflect the actual structure of the population since juveniles were relatively most abundant in the spring and least abundant in the winter. For tagged foxes, however, it is felt that these ratios did not reflect seasonal abundance. The reason apparently lies in the fact that tagged adults, which had survived from earlier years, had scattered over a wide area by spring and early summer when tagged pups occurred only on the study area.

The specimens attributable to various causes of death, for both tagged and untagged foxes, are summarized in Table 2. In both groups, trapping was the chief source of material, but the proportion was much greater among the untagged animals. However, for shooting and highway accidents, the proportions were greater among the tagged animals suggesting that the presence of a tag in such cases increased the likelihood of a donor

TABLE 2. SPECIMENS ATTRIBUTABLE TO VARIOUS CAUSES OF DEATH FOR THE TAGGED AND UNTAGGED RED FOXES EXAMINED

	Foxes examined					
	Juvenile		Adult		Total	
Cause of death	Number	Per cent	Number	Per cent	Number	Per cent
Tagged						
Trapping	76	54	24	41	100	50
Shooting	28	20	22	38	50	25
Highway accident	26	18	4	7	30	15
Miscellaneous*	11	8	8	14	19	10
Total	141	100	58	100	199	100
Untagged						
Trapping	540	73	245	71	785	73
Shooting	97	13	60	18	157	15
Highway accident	62	9	18	5	80	7
Miscellaneous*	38	5	21	6	59	5
Total	737	100	344	100	1,081	100

*Includes foxes found dead, killed by dogs or clubbed by people.

submitting it. Because of this bias, it is felt that these data do not represent the true mortality pattern.

The sex and age ratios for foxes taken at different seasons by methods that either captured them alive (den excavation and live trapping) or killed them (fur trapping and shooting) were compared; specimens found dead from other causes were omitted. The data are given in Table 3. The only significant difference in sex ratio was that between juveniles live trapped in summer and those shot in winter. That the proportion of males was much greater for those shot indicates that juvenile males are more vulnerable to hunters than are juvenile females. This difference in vulnerability has often been attributed to an earlier average time of dispersal and a greater average dispersal distance for juvenile males than for adults. Yet if this were the case, a significantly greater proportion of males should have been

TABLE 3. SEX AND AGE RATIOS FOR RED FOXES TAKEN DURING DIFFERENT SEASONS ON AND IN THE VICINITY OF THE CAYUGA STUDY AREA

Season	Method of capture	Age	Total number	Sex ratio§	Age ratio†
April - May	Den excavation	Juvenile	255	0.94	28.3*
		Adult	9	0.00	
June - September	Live trapping	Juvenile	362	1.03**	4.5
		Adult	80	1.05	
October - March	Fur trapping	Juvenile	610	1.28	2.3*
		Adult	267	0.93	
October - March	Shooting	Juvenile	97	2.13**	1.5*
		Adult	64	1.21	

§Males per female.
†Juveniles per adult.
*Significantly different from other age ratios ($P < 0.05$); also difference in values for April-May (den excavation) and October-March (shooting) highly significant ($P < 0.01$).
**Difference in paired sex ratios highly significant ($P < 0.01$).

TABLE 4. AGE DISTRIBUTION IN ANNUAL FALL WINTER SAMPLES AND AVERAGE MORTALITY BY AGE GROUP FOR RED FOXES FROM CAYUGA STUDY AREA AND VICINITY

Age (years)*	Year§						Average annual mortality for each age group† (per cent)
	1972-73	1973-74	1974-75	1975-76	1976-77	Total	
Under 1	52 (41)	122 (65)	192 (74)	160 (72)	243 (74)	769 (68)	69
1 - 2	39 (31)	29 (15)	33 (13)	36 (16)	43 (13)	180 (16)	53
2 - 3	18 (14)	14 (7)	16 (6)	15 (7)	23 (7)	86 (7)	53
3 - 4	7 (5)	13 (7)	7 (3)	5 (2)	17 (5)	49 (4)	66
4 - 5	2 (2)	1 (1)	4 (2)	3 (1)	2 (1)	12 (1)	46
5 - 6	1 (1)	2 (1)	2 tr	1 (1)	1 tr	7 (1)	50
6 & over	2 (2)	0	2 tr	2 (1)	1 tr	7 (1)	100
Unknown	5 (4)	8 (4)	4 (2)	0	0	17 (2)	xxx
Total	126 (100)	189 (100)	260 (100)	222 (100)	330 (100)	1,127 (100)	xxx

*Determined according to Monson et al. (1972).

§Figures in parentheses represent percentages; tr = trace.

†Disregarding specimens of unknown age.

trapped during the fall and winter, but this did not occur. Although there was no significant difference in sex ratio between the foxes captured in dens in the spring and those live trapped in the summer, there was a highly significant difference in the age ratio. However, the preponderance of pups among the animals captured in dens simply reflected the fact that vixens spent little time in dens. The significant difference in age ratios between foxes trapped for fur and those shot suggests that adults were more vulnerable to hunters than to trappers. This appears to indicate that adults are less cautious than pups when approaching people during the fall and winter.

Since the ratio of juveniles to adults appeared to have been least biased for the specimens collected during the fall and winter, only records for foxes taken during that period were considered in assessing the age structure of the population. The data are given in Table 4. Juveniles comprised from 65 to 74 per cent of the specimens for four of the five years, but only 41 per cent of the 1972-73 sample. A 5 x 2 contingency test (Steele and Torrie, 1960:370) indicated that the juvenile segments of the five samples were not homogeneous and that the variation among them was highly significant ($P < 0.01$). When the 1972-73 sample was omitted, a 4 x 2 contingency test indicated no remaining significant difference. Apparently, juveniles in the 1972-73 population had suffered unusually high mortality, possibly related to an unusually wet spring. Much of central New York was flooded for more than a week in June 1972.

The proportions of tagged red foxes recovered through different causes of death are compared with data for three similar studies in Table 5. Seasonal conditions were assumed to have been comparable. In the work of both Marcstrom (1968) in Sweden and Jensen (1973) in Denmark, the proportion recovered by trapping and shooting combined was significantly greater ($P < 0.01$) than that recorded in the present study. However, the proportion reported by Storm et al. (1976) in the midwestern United States

Table 5. Comparative Proportions Attributable to Different Causes of Death For Recoveries of Tagged Red Foxes As Recorded in Four Investigations*

Cause of death	Marcstrom (1968)§	Jensen (1973)§	Storm et al. (1976)			Present study		
			Adult	Juv-enile	Total	Adult	Juv-enile	Total
Trapping	†	†	14	22	21	41	54	50
Shooting	†	†	76	56	59	38	20	25
Sub-total	97	88	90	78	80	79	74	75
Highway accident	2	5	3	12	11	7	18	15
Miscellaneous	1	7	7	10	9	14	8	10
Total	100	100	100	100	100	100	100	100
Number in sample	59	202	118	665	783	58	141	199

*Figures in per cent.

§Adults and juveniles combined.

†Separate values for trapping and shooting not given.

was not significantly different. For recoveries as a result of highway accidents, the proportion reported by Storm et al. (1976) was not significantly different from that of the present study, while the proportion recorded by Jensen (1973) was significantly less. The latter suggests a difference in public attitude or in the seasonal volume of traffic on Danish roads.

Sarcoptic mange, resulting from infestations of the mange mite (*Sarcoptes scabiei*), appeared to have been the most important natural mortality factor observed in the present study. The seasonal incidence of this disease in the tagged and untagged foxes examined is given in Table 6. Mange was most common in the specimens obtained in the spring and

TABLE 6. SEASONAL INCIDENCE OF SARCOPTIC MANGE IN TAGGED AND UNTAGGED RED FOXES COLLECTED ON AND IN THE VICINITY OF THE CAYUGA STUDY AREA, ACCORDING TO AGE

Age	Season				Total
	Spring	Summer	Fall	Winter	
Tagged					
Juvenile					
Number of specimens	2	43	79	17	141
Incidence of mange					
Number	0	7	5	3	15
Per cent	0	16	6	18	11
Adult					
Number of specimens	9	13	21	15	58
Incidence of mange					
Number	4	8	3	4	19
Per cent	44	62	14	27	33
Total					
Number of specimens	11	56	100	32	199
Incidence of mange					
Number	4	15	8	7	34
Per cent	36	27	8	22	17
Untagged					
Juvenile					
Number of specimens	22	42	641	32	737
Incidence of mange					
Number	17	32	57	4	110
Per cent	77	76	9	13	15
Adult					
Number of specimens	6	16	297	25	344
Incidence of mange					
Number	2	16	51	7	76
Per cent	33	100	17	28	22
Total					
Number of specimens	28	58	938	57	1,081
Incidence of mange					
Number	19	48	108	11	186
Per cent	68	83	12	19	17
Total					
Number of specimens	39	114	1,038	89	1,280
Incidence of mange					
Number	23	63	116	18	220
Per cent	59	55	11	20	17

summer and least common in those for the fall. The incidence was consistently greater among adults than juveniles, a finding that seems attributable to the greater boldness of adults whether mangy or not rather than to their being more susceptible to the disease. Pryor (1956) found sarcoptic mange on 1.3 per cent of 60,846 red foxes submitted for bounty payments in Pennsylvania and observed that the highest incidence of the disease occurred during summer.

Of interest was the higher incidence of mange during the winter than during the fall for both tagged and untagged animals. Stone et al. (1972) observed that mange mites killed all experimentally infested captive red foxes in 2 to 4 months. Because there is no reason to believe that wild foxes would not be killed as rapidly as captives, foxes exposed to mange during the December-January mating season would be expected to succumb from late February through May. Similarly, pups exposed from March through May would be expected to succumb from May through September. Therefore, infested red foxes should be eliminated by late summer or early fall. However, that the disease breaks out again each spring is evidence that some foxes are infested (by other foxes, by other species such as mangy dogs or by incidentally acquiring viable mange mites) late enough to survive into the breeding season. Thus the low point occurs during the fall, and incidence increases during the winter culminating in a peak each year during late spring and summer.

Only 39 mangy red foxes were handled that were in suitable condition for determining the month of exposure (Table 7). Of these, 10 (48 per cent) of 21 adults and 13 (72 per cent) of 18 juveniles had been exposed from April through June and would have succumbed during the summer. This corresponds with the observations of Pryor (1956). Seven (33 per cent) of the 21 adults had been exposed during the winter (breeding season) and

Table 7. Distribution, According to Estimated Month of Exposure to Sarcoptic Mange, of Red Foxes From the Cayuga Study Area and Vicinity

Month of exposure*	Age at recovery		
	Adult	Juvenile	Total§
April	2	. .	2 (5)
May	5	7	12 (31)
June	3	6	9 (23)
July	1	1	2 (5)
August	. .	1	1 (3)
September	. .	3	3 (7)
October	2	. .	2 (5)
November	1	. .	1 (3)
December	. .	. .	. .
January	6	. .	6 (15)
February	1	. .	1 (3)
March	. .	. .	. .
Total	21	18	39 (100)

*Based on chronological development of mange in infested red foxes as described by Stone et al. (1972).

§Figures in parentheses are percentages.

would have died in April and May, in many cases after transmitting mange to other red fox families directly or indirectly through their mangy pups.

Though several red foxes were found that had obviously succumbed to sarcoptic mange alone, most instances of mange were encountered weeks or months before the disease would have caused the death of the host. The virulence of sarcoptic mange mites was demonstrated by Gerasimoff (1953) who killed European red foxes by placing a single gravid female mite upon an individual. On the other hand, Storm et al. (1976) reported the spontaneous recovery of mangy red foxes, but without any evidence that the condition was actually caused by sarcoptic mites.

For tagged and untagged red foxes recovered by shooting, 30 and 50 per cent, respectively, had been mangy (Table 8). The respective proportions for specimens that had been found dead, killed by dogs or clubbed to

TABLE 8. INCIDENCE OF MANGE IN RELATION TO CAUSE OF DEATH FOR TAGGED AND UNTAGGED RED FOXES EXAMINED FROM THE CAYUGA STUDY AREA AND VICINITY

Cause of death	Foxes examined	Incidence of mange		Proportion of mangy foxes (per cent)
		Number	Per cent	
Tagged				
Trapping	100	2	2	6
Shooting	50	15	30	44
Highway accident	30	5	17	15
Miscellaneous	19	12	63	35
Total	199	34	17	100
Untagged				
Trapping	785	42	5	23
Shooting	157	78	50	42
Highway accident	80	26	33	14
Miscellaneous	59	40	68	21
Total	1,081	186	17	100

death by people were 63 and 68 per cent. The incidence of mange among foxes that had been trapped was lowest, probably trapping was most effective in the fall after most victims of the summer mange outbreak had died. In contrast, mangy specimens attributable to other causes of death tended to be encountered most often during the spring and summer.

The observations of the present study suggest the following epidemiology for sarcoptic mange in red foxes. Since mange mites survive no longer than 10 days on a dead host or in soil (Gerasimoff, 1953), they would not be expected to overwinter in fox dens. Also, most infested red foxes die before the beginning of the fall season. Nevertheless, a few carriers survive into the next breeding season. Females, traditionally considered monogamous or solitary, have been found to mate repeatedly, anestrously and estrously, for several weeks in midwinter (Lloyd, 1975) and with more than one male (Storm et al., 1976). Adult males are also probably polygamous if more than one receptive female is available (Burrows, 1968:138). This promiscuous mating behavior, depending upon the density of the breeding

population, provides a varying range of direct contact which facilitates the spread of mange. Since pups are born within 52 days after successful mating, a vixen that had acquired mange during one of numerous nuptial experiences would be expected to live (2 to 4 months) from 8 to 68 days after whelping in March. The pups of mangy vixens exposed during breeding become mangy soon after birth. While some pups may sucumb with the vixen, mangy pups may be expected to emerge from the dens in April, and such a litter was actually found (Tullar et al., 1974).

The occurrence of mangy vixens and their litters in April is a multiple threat to healthy fox famlies occupying nearby dens. Mangy adults (males and females) were found to visit dens of other families, presumably to glean food remains that began to accumulate in April. Small mangy pups that survived long enough to emerge from dens were also threats when abandoned by sick mothers. Such pups utter cries that are attractive to other foxes. Adult red foxes have been found to foster orphaned pups (Sheldon, 1950; Pils and Martin, 1974; Tullar et al., 1974). Such an act exposes to mange all the members of the foster family sharing the same den.

The most rampant stage of mange spreading appeared to take place in late May and June when pups dispersed from the dens and mingled with pups of nearby families that had fostered mangy pups or had been contaminated by mangy adults. By June, mangy adults exposed during breeding had succumbed, often with their pups, but the fostering families were supporting rapidly developing mange infestations. Pups and adults exposed during June dispersal became conspicuously mangy during August, and all had succumbed by the end of October. These were the mangy foxes most likely to have been found and killed by landowners or other concerned people. They accounted for the summer peaks of mange incidence.

As fall approached, contacts between red foxes of all ages diminished, and there was a corresponding decrease in mange among those shot or trapped for fur. Data from other parts of the range of the species apparently reflect the same relationship. Storm et al. (1976) reported averages of 1 and 2 per cent, respectively, from two regions of Iowa in the incidence of mange among red foxes taken for fur during the period 1966-67 to 1971-72. Pils and Martin (1978) noted that furbuyers in Wisconsin reported the incidence of mange to have been 7 per cent in 1974-75 and 4 per cent in 1975-76 in the red fox pelts they handled.

Free-ranging dogs are also potential mange vectors. Stone et al. (1972) demonstrated that sarcoptic mites from red foxes infest domestic dogs but often do not kill them. In the present study, dogs were seen to dig at red fox dens in April, and dogs had killed several tagged and untagged mangy foxes that were collected in the spring and summer. Pils and Martin (1974) also reported an adult female red fox killed by a dog at her den. Because some dogs roam more than 2 miles (Scott and Fuller, 1965:62), these

animals could spread mange to widely distributed, isolated red fox families even when fox populations were very low.

Estimates of red fox populations on the study area during the summer (based on occupied dens found and foxes live trapped) and the proportion examined from the study area and vicinity are presented in Table 9 together with the associated incidence of mange. The number examined from year to year (which included those found that had succumbed to accidents and disease as well as those shot and trapped) comprised 15 to 33 per cent of the corresponding summer populations. Therefore, it is doubtful that the mortality recorded had limited the abundance of red foxes on the area. At the same time the area could have supported nearly twice the number of families each summer as indicated by the fact that the 27 families found in 1973 occurred on only 43 of the 100 sections whereas 79 sections were occupied during at least one year (Tullar and Berchielli, 1980).

Mange infestations were found on 46 and 45 per cent of the red foxes collected from the area during the first two years when the estimated number of families was 21 and 27, respectively. However, in the summers of 1974 and 1975, when there were still 25 or more families on the area, the recorded incidence of mange was lowest. Yet observations indicated that by early winter in all four years the population had been reduced to about the same low level. There was no evidence that the prevalence of mange had abated during the summers of 1974 and 1975, but why a greater number of mangy foxes were not found is unknown. Nevertheless, it was concluded that the effect of mange infestations on red fox abundance varies directly with population density.

The composite age distribution among the red foxes collected from the study area and vicinity indicated a growing population with an average juvenile component of 69 per cent. Such a population would have been expected to have increased to occupy all suitable habitat. However, abundance from summer to summer fluctuated relatively little, and only 2.3 per cent of these foxes lived beyond 4 years. This indicates a high rate of population turnover and a limited survival of all age groups. Sarcoptic mange appears to have been the only mortality factor observed that could have caused such population characteristics. It can reduce a population without disturbing its age structure because all individuals are equally susceptible and whole families often succumb together. Since mange is most devastating to red foxes during the late spring and early summer, a fox population occurred each fall that was greatly reduced but exhibited a potential for rapid growth. A high rate of productivity is necessary to compensate for an equally high mortality rate.

Because there were several sources of human bias, the collections of foxes from the study area and vicinity probably did not fully reflect the mortality patterns of the red fox population. Nevertheless, it was evident that intentional harvesting (i.e., sport hunting and fur trapping under

Table 9. Estimated Levels of Red Fox Population on the Cayuga Study Area During the Summer and Incidence of Mange in Specimens Examined During the Full Year and During the Spring and Summer From the Area and Vicinity

Year	Estimated summer population		Foxes examined (full year)				Incidence of mange during spring and summer		
			Total		Mangy		Mangy families	Estimated mangy foxes	
	Families*	Foxes§	Number	Per cent†	Number	Per cent‡		Number§	Per cent†
1972-73	21	181	28	15	13	46	9	77	43
1973-74	27	232	55	24	25	45	17	146	63
1974-75	25	215	71	33	7	10	4	34	16
1975-76	28	241	67	28	4	6	0	0	. .
1976-77	26	224	58	26	16	28	8	69	31
Total	127	1,093	279	26	65	23	38	326	30

*Based on occupied dens found and foxes captured on study area.

§Derived from number of families at ratio of two adults plus 6.6 young per family.

†Proportion of estimated summer population.

‡Proportion of total examined.

law) and accidental mortality alone could not have caused the consistently low level of the fall population. Sarcoptic mange apparently was the principal additional factor involved. However, reduced intraspecific contact, as surviving vixens become widely scattered in a population decline, appears to prevent complete extirpation of red foxes by sarcoptic mange. Then, as the population increases again, such contacts necessarily increase also, the first stage of another mange outbreak. Fox harvesting (in the fall and winter) serves to further reduce and scatter the population so that breeding groups and subsequent litters are fewer the following spring. If such harvesting were stopped, the number of foxes succumbing to sarcoptic mange would increase with a corresponding waste of red fox fur.

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COMPARATIVE FOOD SELECTION BY COEXISTING SUBYEARLING COHO SALMON, CHINOOK SALMON AND RAINBOW TROUT IN A TRIBUTARY OF LAKE ONTARIO[1]

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ABSTRACT

The stomach contents of 370 subyearling coho salmon, chinook salmon and rainbow trout occupying the same section of a New York tributary of Lake Ontario were examined during the period from May through October in 1978. Aquatic invertebrates, mainly ephemeropterans and chironomids, predominated in the foods taken during the first month after emergence, while subsequently their mean monthly contribution to the diet was 21, 37 and 54 per cent for the three species, respectively. From July to October, the average monthly overlap in diet between coho salmon and chinook salmon (0.5781) was essentially identical to that between chinook salmon and rainbow trout (0.5780), while that between coho salmon and rainbow trout was 0.4933. In this stream during the study, the salmon occupied pools and the trout riffles. Comparison of the feeding data for 1978 with data for coho salmon and rainbow trout in the stream in 1977 suggested that coho salmon may have shifted their diet toward allochthonous prey when chinook salmon were present.

Along the west coast of North America the feeding ecology of juvenile coho salmon (*Oncorhynchus kisutch*) was examined by Chapman (1966), Mundie (1969) and Mason (1976); that of chinook salmon (*O. tshawytscha*) by Becker (1970, 1973) and Loftus and Lenon (1977); and that of rainbow trout (*Salmo gairdneri*) by Shapovalov and Taft (1954). In the Great Lakes region, Hannuksela (1973), Wagner (1975) and Johnson and Ringler (1980) studied the food habits of juvenile coho salmon and rainbow trout. Prior to the present study, however, data on the food habits of juvenile chinook salmon in tributaries of the Great Lakes were lacking. Although some of the studies cited involved two of these species existing together, none applied to all three.

Chinook salmon spawn earlier than coho salmon; in New York tributaries of Lake Ontario the peak occurs in mid-October. For coho salmon the peak usually occurs during early to mid-November. In general, chinook salmon spawn in the larger tributaries such as the main Salmon River in Oswego County, although spawning of both species does occur in some smaller tributaries. Rainbow trout spawn over a more extended period than do the salmon, but most such activity occurs during April and May. Most salmon fry emerge during May and June, while rainbow trout begin emerging in June and continue until early August in some streams.

During studies in 1977 on five tributaries of the Salmon River (Johnson, 1978) natural reproduction of coho salmon and rainbow trout was substantial, but that of chinook salmon was extremely low. Also, the interactive

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ecology of subyearling coho salmon and rainbow trout in one of the streams was studied (Johnson and Ringler, 1980). In 1978, a strong year class of chinook salmon, in combination with coho salmon and rainbow trout, made it possible to examine this relationship among all three species occurring together in the same stream. The objectives were to examine their food habits under these conditions and to detect shifts in the diet of coho salmon and rainbow trout that might be caused by the presence of chinook salmon in 1978.

MATERIALS AND METHODS

The study stream, Orwell Brook in Oswego County (N.Y.), is located on the Tug Hill plateau, a region subject to severe winters. It is a major tributary of the Salmon River which discharges into Lake Ontario at Port Ontario (Figure 1). The average monthly summer discharge of Orwell Brook in 1978 was 0.26 cubic meter per second, a reduction of 25 per cent from 1977. Ranges of 8.3-8.8 ppm in dissolved oxygen, 54-109 umhos in specific conductance and 7.4-7.8 in pH were recorded during the summer of 1977 (Haggerty, 1977), and Johnson (1978) listed the fish identified.

Subyearling salmonids were collected for stomach analysis from May through October, and the later-emerging rainbow trout from July through October. Specimens were collected once each month between 11:00 a.m. and 1:00 p.m. with a 3-meter minnow seine and were placed in 10 per cent formalin with 10 munutes of collection to inhibit digestive processes. In the laboratory they were weighed and measured (total length). A correction

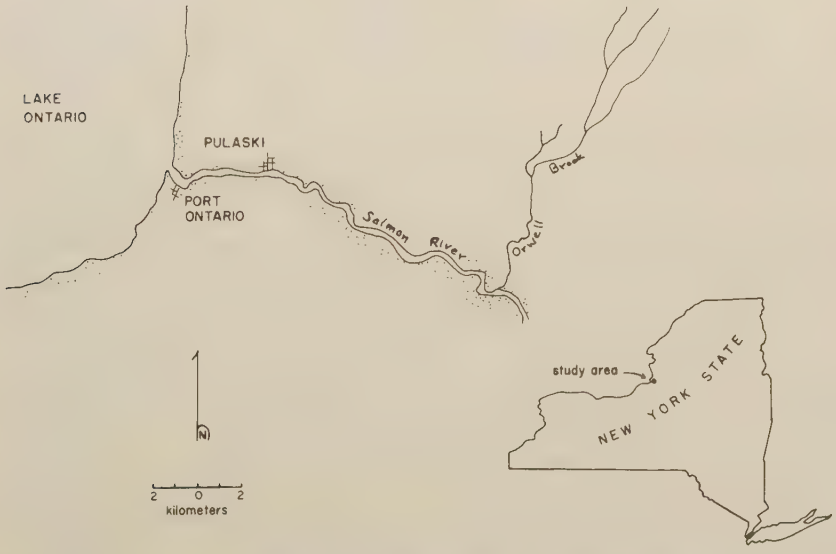

Figure 1. Map showing location of the Salmon River and Orwell Brook.

factor (Stauffer, 1971) was used to account for length shrinkage due to preservation. The stomach of each was then removed for examination.

Aquatic prey were usually identified to family, whereas terrestrial prey were identified to order. Items with no caloric value (e.g., trichopteran cases) were not included in the diet composition. The relative contribution of each prey taxon was estimated by dry weight. A representative number of individuals of each taxon were weighed at 105 ° C. for 24 hours and then placed in a desiccator for 6 hours prior to being weighed on an analytical balance. The total for the sample was divided by the number of specimens to estimate the dry weight per individual.

Diet overlap values were calculated by using the equation of Morisita (1959) as modified by Horn (1966)

$$C\lambda = 2 \frac{\sum_{i=1}^{s} XiYi}{\sum_{i=1}^{s} Xi^2 + \sum_{i=1}^{s} Yi^2}$$

where:

$C\lambda$ = overlap coefficient

s = total items in both categories

Xi = proportion of total diet of fish species X contributed by food taxon i

Yi = proportion of total diet of fish species Y contributed by food taxon i

RESULTS

A total of 370 subyearling salmonids comprising 140 coho salmon, 120 chinook salmon and 110 rainbow trout were examined (Table 1). Following emergence in May, coho salmon fed primarily on aquatic invertebrates

Table 1. Number and Size of Subyearling Salmonids From Orwell Brook Examined Each Month in 1978

	Coho salmon			Chinook salmon			Rainbow trout		
		Length*			Length*			Length*	
Month	Number	Mean	Range	Number	Mean	Range	Number	Mean	Range
May	10	45	33- 59	10	37	31-46	. .	. .	. .
June	20	64	40- 80	20	47	41-56	. .	. .	. .
July	40	71	56- 88	40	65	48-81	30	45	33-52
August	30	75	65 -91	20	66	57-80	25	52	41-61
September	20	82	66- 98	20	69	61-83	30	57	44-70
October	20	84	70-106	10	76	70-85	25	62	52-74

*Total length in millimeters.

(86 per cent) with ephemeropterans (57 per cent) and chironomids (19 per cent) being the major prey (Table 2). After May, terrestrial invertebrates dominated their diet (60 to 91 per cent), the major foods being homopterans, dipterans, hymenopterans and coleopterans. Chironomids,

TABLE 2. DIETARY COMPOSITION, AS PERCENTAGE OF DRY WEIGHT, OF STOMACH CONTENTS OF 140 SUBYEARLING COHO SALMON COLLECTED FROM ORWELL BROOK FROM MAY TO OCTOBER

Taxon	May	June	July	August	September	October
Aquatic foods						
Cladocera	. .	. .	0.01	. .	. .	. .
Hydracarina	. .	0.04	0.23	0.16	0.11	. .
Collembola	. .	1.33	0.31	0.06	0.25	0.14
Plecoptera						
Leuctridae	. .	1.85	. .	. .	. .	. .
Perlidae	. .	. .	7.27	. .	. .	. .
Unidentified	8.99	1.30	. .	. .	. .	0.84
Ephemeroptera						
Baetidae	3.00	1.82	0.68	0.60	1.36	. .
Heptageniidae	3.99	. .	. .	. .	. .	. .
Leptophelebiidae	17.97	4.39	. .	. .	. .	0.70
Unidentified	32.29	10.21	5.22	2.90	1.24	4.21
Trichoptera						
Hydropsychidae	. .	0.83	. .	0.36	1.45	0.56
Odontoceridae	. .	. .	. .	0.60	. .	2.10
Philopotamidae	0.67	. .	. .	. .	. .	. .
Unidentified	. .	1.16	2.31	0.96	. .	4.26
Hemiptera						
Veliidae	. .	. .	. .	. .	. .	1.40
Coleoptera						
Dytiscidae	. .	0.13	0.07	. .	. .	. .
Elmidae	. .	. .	0.20	. .	. .	1.12
Diptera						
Ceratopogonidae	. .	0.04	0.02	0.16	0.05	0.37
Chironomidae	19.12	15.75	4.70	3.36	6.15	4.19
Simuliidae	. .	0.69	. .	. .	. .	. .
Tipulidae	. .	. .	6.19	. .	. .	. .
Blacknose dace	. .	. .	. .	. .	29.00	. .
Total	86.03	39.54	27.21	9.16	39.61	19.89
Terrestrial foods						
Annelida	6.65	. .	. .	. .	. .	. .
Arachnida	. .	1.95	2.49	2.05	3.42	14.63
Coleoptera	. .	9.74	14.12	10.72	10.73	6.27
Dermaptera	3.70	0.52	2.64	1.38	. .	. .
Diplopoda	. .	. .	3.51	. .	. .	. .
Diptera	3.62	6.51	6.62	19.90	16.98	20.78
Hemiptera	. .	8.92	4.68	0.52	3.09	4.46
Homoptera	. .	19.48	13.16	17.07	7.24	22.31
Hymenoptera	. .	10.87	20.15	9.97	6.97	11.66
Lepidoptera	. .	2.47	5.42	29.23	1.09	. .
Orthoptera	. .	. .	. .	. .	10.87	. .
Total	13.97	60.46	72.79	90.84	60.39	80.11

ephemeropterans and trichopterans were the major aquatic taxa taken by coho salmon during this period. Three young-of-the-year blacknose dace (*Rhinichthys atratulus*) 21 to 27 millimeters long comprised 29 per cent of the stomach contents of September specimens and were the only other major aquatic prey taken.

Like coho salmon, recently-emerged chinook salmon in May fed heavily on aquatic invertebrates (96 per cent), mainly ephemeropterans (64 per

Table 3. Dietary Composition, As Percentage of Dry Weight, of Stomach Contents of 120 Subyearling Chinook Salmon Collected From Orwell Brook From May to October in 1978

Taxon	May	June	July	August	September	October
Aquatic foods						
Oligochaeta	. .	0.06	. .	. .	. .	. .
Hydracarina	. .	. .	0.23	0.34	. .	. .
Decapoda	. .	. .	. .	. .	. .	3.31
Collembola	. .	0.58	0.25	0.66	1.30	0.17
Plecoptera						
Chloperlidae	. .	. .	. .	. .	. .	0.86
Unidentified	. .	. .	. .	. .	2.28	. .
Ephemeroptera						
Baetidae	9.17	2.36	1.14	2.67	1.48	1.02
Ephemerellidae	. .	. .	1.91	. .	2.96	. .
Heptageniidae	. .	. .	0.43	. .	. .	2.58
Leptophlebiidae	18.34	1.10	0.48	. .	. .	0.83
Unidentified	36.68	19.04	12.18	3.68	2.30	. .
Tricoptera						
Glossosomatidae	. .	. .	0.28	. .	. .	. .
Hydropsychidae	. .	4.53	1.52	1.97	. .	0.98
Limnephilidae	. .	. .	. .	. .	. .	9.30
Odontoceridae	. .	. .	. .	. .	. .	16.39
Philopotamidae	3.06	. .	. .	. .	. .	1.32
Unidentified	. .	2.61	2.78	2.59	. .	. .
Coleoptera						
Dytiscidae	. .	. .	1.69	. .	. .	. .
Haliplidae	. .	. .	3.05	. .	. .	. .
Diptera						
Ceratopogonidae	. .	0.10	0.29	. .	. .	0.32
Chironomidae	28.47	12.87	15.20	16.02	17.55	3.03
Simuliidae	. .	0.79	0.68	. .	. .	. .
Tipulidae	. .	. .	. .	. .	. .	0.41
Total	95.72	44.04	42.11	27.93	27.87	40.52
Terrestrial foods						
Arachnida	. .	0.63	7.53	. .	4.45	12.77
Coleoptera	. .	13.94	5.67	13.61	10.38	20.43
Dermaptera	4.28	0.59	1.24	. .	0.37	. .
Diptera	. .	10.19	8.79	43.58	22.24	7.54
Hemiptera	. .	9.44	6.12	2.83	17.05	6.37
Homoptera	. .	14.11	17.23	2.85	6.67	5.74
Hymenoptera	. .	3.55	8.77	9.20	8.89	1.66
Lepidoptera	. .	3.51	2.54	. .	2.08	4.97
Total	4.28	55.96	57.89	72.07	72.13	59.48

TABLE 4. DIETARY COMPOSITION, AS PERCENTAGE OF DRY WEIGHT, OF STOMACH CONTENTS OF 110 SUBYEARLING RAINBOW TROUT COLLECTED FROM ORWELL BROOK FROM JULY TO OCTOBER IN 1978

Taxon	July	August	September	October
Aquatic foods				
Turbellaria	. .	. .	. .	1.01
Oligochaeta	. .	0.13	0.11	. .
Hirudinea	. .	. .	0.70	. .
Hydracarina	0.16	0.25	0.14	. .
Collembola	0.93	. .	0.35	0.07
Plecoptera				
Leuctridae	0.23	. .	. .	. .
Perlidae	. .	. .	. .	9.14
Perlodidae	. .	. .	. .	0.70
Unidentified	. .	. .	1.75	0.84
Ephemeroptera				
Baetidae	5.43	23.42	10.08	3.37
Ephemerellidae	5.69	. .	1.72	1.19
Ephemeridae	. .	. .	. .	1.41
Heptageniidae	. .	. .	3.72	2.50
Leptophlebiidae	. .	1.19	0.18	2.25
Unidentified	12.29	7.85	1.84	1.48
Tricoptera				
Glossosomatidae	0.62	. .	0.18	0.84
Helicopsychidae	. .	. .	4.48	. .
Hydropsychidae	2.17	1.42	2.19	8.05
Hydroptilidae	. .	. .	. .	0.21
Odontoceridae	0.77	1.58	7.01	4.36
Philopotamidae	. .	. .	. .	0.70
Unidentified	0.93	0.32	2.63	1.05
Hemiptera				
Veliidae	. .	. .	. .	0.42
Coleoptera				
Dytiscidae	1.09	. .	. .	. .
Psephenidae	6.58	. .	. .	. .
Doptera				
Ceratopogonidae	0.05	0.52	0.11	0.63
Chironomidae	20.61	9.24	16.71	6.31
Dixidae	0.53	. .	. .	. .
Simuliidae	2.48	1.69	1.40	. .
Tipulidae	0.19	. .	8.81	2.25
Gastropoda	. .	. .	. .	1.09
White sucker (larvae)	1.55	. .	. .	. .
Total	62.30	47.61	64.11	49.87
Terrestrial foods				
Arachnida	1.33	4.75	3.38	8.43
Coleoptera	. .	22.15	1.96	3.47
Dermaptera	1.55	3.16	0.53	. .
Diplopoda	. .	. .	0.87	. .
Diptera	2.26	4.73	3.78	5.13
Hemiptera	2.33	1.36	9.89	6.95
Homoptera	6.50	2.74	4.96	9.28
Hymenoptera	13.71	0.95	5.29	15.46
Lepidoptera	10.02	10.97	5.23	1.41
Neuroptera	. .	1.58	. .	. .
Total	37.70	52.39	35.89	50.13

cent) and chironomids (28 per cent) as shown in Table 3. Although after May they fed more heavily on terrestrial invertebrates than did the coho salmon, their use of aquatic invertebrates was also higher. Their principal terrestrial prey were dipterans, coleopterans, homopterans, hemipterans and hymenopterans. The major aquatic taxa represented were ephemeropterans (6 to 23 per cent), chironomids (3 to 18 per cent) and trichopterans (0 to 28 per cent).

Subyearling rainbow trout fed more heavily on aquatic invertebrates (48 to 64 per cent) than did either species of salmon (Table 4). The primary aquatic components eaten by the trout were ephemeropterans, chironomids and trichopterans hymenopterans, lepidopteran larvae, coleopterans, homopterans and hemipterans were the chief terrestrial invertebrates taken.

In estimating diet overlap among subyearling salmonids, the 23 food categories were the same as those used by Johnson and Ringler (1980) in comparing the diets of subyearling coho salmon and rainbow trout with the composition of the drift and bottom fauna of Orwell Brook during 1977. Values may vary from 0, when samples contain no foods in common, to 1, when samples are identical in the proportional representation of food categories. In 1978, the overlap between coho salmon and chinook salmon generally decreased from May through October (Table 5). The overlaps between coho salmon and rainbow trout, and between chinook salmon and rainbow trout, did not follow this pattern. In general, the overlaps among all three species were lowest during late summer (i.e., August and September). From July to October, when all three species were occurring together in Orwell Brook, the average monthly diet overlap between coho

Table 5. Diet Overlap Between Subyearling Coho Salmon, Chinook Salmon and Rainbow Trout in Orwell Brook From May to October in 1978

Month	Species	Overlap value
May	Coho salmon - chinook salmon	0.8355*
June	Coho salmon - chinook salmon	0.8914*
July	Coho salmon - chinook salmon	0.7404*
	Coho salmon - rainbow trout	0.5741
	Chinook salmon - rainbow trout	0.7238*
August	Coho salmon - chinook salmon	0.5768
	Coho salmon - rainbow trout	0.4899
	Chinook salmon - rainbow trout	0.3363
September	Coho salmon - chinook salmon	0.5297
	Coho salmon - rainbow trout	0.2185
	Chinook salmon - rainbow trout	0.5731
October	Coho salmon - chinook salmon	0.4654
	Coho salmon - rainbow trout	0.6907*
	Chinook salmon - rainbow trout	0.6788*

*Denotes significant overlap.

salmon and chinook salmon (0.5781) was essentially identical to that between chinook salmon and rainbow trout (0.5780). The corresponding overlap between coho salmon and rainbow trout was 0.4933.

Diet overlap values of 0.60 or more are generally considered significant (Zaret and Rand, 1971). Therefore a significant overlap occurred between coho salmon and chinook salmon during the first three months after emergence but not thereafter. In May this resulted from similar use of ephemeropterans and chironomids. During June and July mutual predation on terrestrial insects, primarily homopterans, coleopterans and hymenopterans, was the principal cause. Feeding on ephemeropterans and chironomids also contributed to the high diet association in June.

Similar predation on aquatic invertebrates, mostly ephemeropterans, chironomids and trichopterans, resulted in significant diet overlaps between subyearling chinook salmon and rainbow trout in July and October. Terrestrial invertebrates of importance at this time were hymenopterans in July and arachnids in October. A high diet association between coho salmon and rainbow trout in October reflected extensive feeding on allochthonous[2] prey by both species.

DISCUSSION

Mundie (1969), Wagner (1975), Mason (1976) and Johnson and Ringler (1981) reported that chironomids numerically dominate the diet of recently-emerged coho salmon. In the present study, although they contributed only 19 per cent by dry weight in May, chironomid larvae, pupae and adults numerically comprised 29, 12 and 15 per cent, respectively, of the food taken by such salmon in Orwell Brook. Similarly, Becker (1970, 1973) found that chironomids numerically made up 81 per cent of the diet of young salmon in Washington. For chinook salmon in Orwell Brook during May, the corresponding proportion was 46 per cent. Chironomids are undoubtedly important to the diet of juvenile salmon but, because of their small size and low caloric value in relation to most prey eaten (Cummins and Wuycheck, 1971), numerical representation may overestimate their importance during most of the year. It is likely that chironomids are most important to recently-emerged salmon. Their small size and generally poor swimming ability led Johnson and Ringler (1981) to suggest that the density, size and species involved may be vitally important during the early stages of exogenous feeding of recently-emerged coho salmon.

Terrestrial invertebrates are reported to dominate the summer and early autumn diets of juvenile coho salmon (Demory, 1961; Chapman, 1966), but subyearling rainbow trout feed primarily on benthos (Hannuksela, 1973; Wagner, 1975). Johnson and Ringler (1980) found that allochthonous foods were the principal component of the diurnal diet of

[2]Originating outside the aquatic habitat.

subyearling coho salmon, whereas in Orwell Brook during the previous summer rainbow trout fed on autochthonous[3] prey. In general the summer diet of these species was similar in 1977 and 1978 with allochthonous invertebrates generally being more dominant in 1978. However, large differences between years occurred in October. Salmon eggs comprised over 90 per cent of the food taken by both subyearling coho salmon and rainbow trout during October in 1977 (Johnson and Ringler, 1979), while they were not recorded in 1978, probably because of a smaller and later spawning run of coho salmon and chinook salmon and a 2-week earlier date of collection.

Although chinook salmon fed more heavily than coho salmon on aquatic invertebrates in Orwell Brook, 63 per cent of their diet was allochthonous in origin. These findings are in sharp contrast to those reported elsewhere for subyearling chinook salmon. West-coast investigators found aquatic insects to be the principal prey of young chinook salmon (Becker, 1970, 1973; Loftus and Lenon, 1977). However, these salmon were examined during the spring and early summer when terrestrial insects are less active and abundant than in late summer and early fall (Giger, 1973; Loftus and Lenon, 1977). There is no available information on the food habits of juvenile chinook salmon in the Great Lakes region, and these fish were too scarce in Orwell Brook during 1977 to adequately assess their diets.

In 1978 both coho and chinook salmon began to emerge in Orwell Brook during the same week (May 7-13). At any given time, however, coho salmon were slightly larger than chinook salmon. Rainbow trout whose emergence was approximately 6 to 8 weeks later were, on the average, at least 22 millimeters shorter than coho salmon during any month (Table 1). Consequently, it may be assumed that coho salmon asserted social dominance over the other species. Such dominance has been reported by Hartman (1965) and Stein et al. (1972).

Although quantitative determinations of habitat selection by sympatric[4] coho salmon, chinook salmon and rainbow trout in Orwell Brook were not made, observations during the collection of these fish and in connection with estimates of production in 1978 (Johnson, 1980) warrant discussion. A similar pattern of segregation of subyearling coho salmon in pools and rainbow trout in riffles, as observed in 1977 (Johnson and Ringler, 1980), was again noted in 1978. The presence of chinook salmon, which were extremely scarce during the summer of 1977 (less than 1 per 100 meters of stream) and abundant in 1978 (107 per 100 meters), asserted no discernible effect on the habitat selection of either coho salmon or rainbow trout. In general, chinook salmon and coho salmon occupied similar areas,

[3]Indigenous to the aquatic habitat.

[4]Occupying the same range without loss of identity from interbreeding.

although coho salmon were more abundant in the deeper pools (1 meter or more deep).

Johnson and Ringler (1980) suggested that food selection by sympatric subyearling coho salmon and rainbow trout in Orwell Brook during 1977 was influenced by the habitat occupied. They observed that the diet composition of coho salmon in pools was closely associated with the composition of invertebrate drift, while the diet of rainbow trout was more closely associated with the bottom fauna. They speculated that these relationships may reflect the relatively high standing crop of benthic invertebrates in riffle areas and the long time during which a pool inhabitant can observe drifting prey. Observations in 1978 supported these hypotheses. For all three species following the first month of feeding, benthic invertebrates comprised 54 per cent of the food taken by the riffle occupant (i.e., rainbow trout), whereas terrestrial prey comprised 79 and 63 per cent, respectively, of the food taken by the two pool dwellers (i.e., coho salmon and chinook salmon).

To examine the possible effects of a strong year class of chinook salmon on the feeding of sympatric coho salmon and rainbow trout in Orwell Brook, data from 1977 (Johnson, 1978; Johnson and Ringler, 1980) were compared with those recorded in 1978 using the same 23 prey categories. The average monthly overlap between years in the diet of coho salmon was 0.5830 (range 0.3947-0.7862) while for rainbow trout it was 0.7081 (range 0.4465-0.9237). For rainbow trout the overlap between years was significant, while for coho salmon it was not. Although the level of significance (i.e., 0.60 or more) is somewhat arbitrary, these data do suggest that there was less similarity between 1978 and 1977 in the diet of coho salmon than in that of rainbow trout. The largest difference in the food taken by coho salmon in the two years was a lower consumption of aquatic invertebrates in 1978 (25 per cent of the average monthly diet) than in 1977 (35 per cent). The differences in diet were not reflected in the abundance of available prey between the years (Johnson and Ringler, 1980 and unpublished data).

Since chinook salmon generally feed on autochthonous prey (Becker, 1970, 1973; Loftus and Lenon, 1977), their presence in Orwell Brook in 1978 in the same physical habitat as coho salmon may have caused the latter to shift to a more allochthonous diet. Stein et al. (1972) observed that, when occurring in sympatry with chinook salmon, subyearling coho salmon occupied the upstream end of riffles where drifting foods were first available. This would help explain the higher use of allochthonous food by coho salmon in 1978, since terrestrial prey dominated the invertebrate drift in Orwell Brook during the day when samples were taken (Johnson and Ringler, 1980 and unpublished data). Conversely, the presence of chinook salmon in 1978 would appear to have had a smaller impact on the feeding of rainbow trout since the latter predominantly occupied riffles in 1977 and 1978 and were spatially segregated from chinook salmon in 1978.

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THE ANNUAL WEIGHT CYCLE AND SURVIVAL OF WHITE-TAILED DEER IN NEW YORK[1]

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ABSTRACT

White-tailed deer exhibit a sinusoidal pattern of weight change over the annual cycle, with a maximum and minimum weight during each year. Expression of these weights changes with continuous mathematical functions is especially useful in evaluating bioenergetics. Regression correlations for the maximum and minimum weights of deer of different ages, combined with two sine functions that adjust the phases of the sine waves to coincide with the times of occurrence of maximum and minimum weights, are used in fairly lengthy but easy-to-use equations for deer of each sex and any age. Equations may be derived for any local population for which annual maximum and minimum weights are available, and the method used for deriving them may be applied to other large mammals too. Comparisons of weights and fat reserves of deer from three regions of New York help explain why winter mortality is very likely to occur in the Adirondacks, and less likely in Central New York and the Southern Tier.

Many biological functions of individual animals are weight dependent, and the mathematical expression of weight over the annual cycle is especially useful in analyzing bioenergetics. Baseline metabolism (Moen, 1978), ecological metabolism (Moen, 1973, 1978) and reproduction rates (Hesselton and Sauer, 1973) are weight-related calculations for white-tailed deer (*Odocoileus virginianus*). Weights of deer may be used as the independent variable in estimating surface areas when calculating thermal exchange (Moen, 1973), and in estimating belly heights and the heights of forage reached which are important considerations when snow restricts deer movement and the availability of forage. The amount of forage needed to meet metabolic needs is partly weight-related because large animals require more forage than small ones. Fat reserves, an important part of the annual weight cycle, are of ecological importance as a reserve supply of energy. Seasonal variations in deer weight should also be considered when using immobilizing agents because weight is a partial determinant of the dosage required (Jacobsen et al., 1976).

Early observations of winter weight losses led to concern that deer often suffered from inadequate diets (Davenport, 1939; Taylor, 1956). It is now evident that deer lose weight during the winter even when their diet is adequate; seasonal weight fluctuations are a characteristic of the normal annual cycle. Weight changes of mature male deer are related to their sexual cycle and to forage resources. Maximum weights were observed by Long et

[1]Deer research at the Wildlife Ecology Laboratory is supported by the New York Department of Environmental Conservation through Federal Aid in Fish and Wildlife Restoration Project W-124-R and by the College of Agriculture and Life Sciences at Cornell University.

al. (1965) in October just prior to breeding, and minimums in March after a period of less favorable range conditions. Sauer (1973a, 1973b) observed similar patterns of seasonal weight change for males, while females reached their minimum weight in the summer during lactation. These patterns have also been observed for the deer at the Wildlife Ecology Laboratory at Cornell University. Seasonal changes in weight are not unique to northern whitetails exposed to harsh winter conditions. Deer in Louisiana also showed seasonal variations in food consumption and weight (Fowler et al., 1967).

One important feature of weight data over the annual cycle is the sinusoidal pattern of change. This paper presents changes in the weight of white-tailed deer through successive annual cycles as assymmetrical sine waves. The derived equations are used to predict weights of male and female deer at any age from birth through physical maturity in the Adirondack, Catskill, and Central and Southern Tier regions of New York.

METHODS

The equations are derived by fitting data for annual maximum and minimum weights on a curve in relation to age, and then determining phase corrections in the sine expressions for the time of year when these weights are reached. Complete step-by-step details were given by Moen (1980); the basic ideas are summarized here. For convenience, the following abbreviations have been adopted for various terms used.

AGDA	age in days
CDWE	calculated death weight—exposed area
CDWS	calculated death weight—sheltered area
CLWK	calculated live weight in kilograms
FEPF	number of fetuses per female
FWAB	fetus weight at birth
JDAY	cumulative day of year according to Julian calendar
AJDA	adjusted Julian day
MAWK	maximum weight in kilograms
MIWK	minimum weight in kilograms
ODWE	observed death weight—exposed area
ODWS	observed death weight—sheltered area
PRPC	primary phase correction
SEPC	secondary phase correction

The first step in deriving a continuous function for expressing weights through the annual cycle is to determine the best-fitting regression equa-

tion for maximum weight. This equation is determined by designating the ages at which the animals reach maximum weight each year as the independent variable (X = age in days = AGDA) and maximum weights as the dependent variable (Y = maximum weight in kilograms = MAWK). Most deer weights reported in the literature are field-dressed weights of hunter-killed animals, so curve fitting must usually be preceded by conversion of field-dressed weight to live weight. Further, hunter-killed deer are often in a weight decline (Moen, 1973), so adjustment upward to an estimated earlier maximum weight may be necessary. To determine the best fit, the AGDA and MAWK values are entered in curve-fitting programs, i.e.,

linear:	$Y = a + bX$
power:	$Y = aX^b$
logarithmic:	$Y = a + \ln X$
exponential:	$Y = ae^{bX}$

The second step is to determine the best-fitting equation for minimum weight. The procedures are the same as for maximum weight except that Y' represents the minimum weight in kilograms (MIWK). Such equations have also been determined for observed death weights in exposed areas (ODWE) and in sheltered areas (ODWS) in each of the three regions.

The regression equations with the best fits are generally determined by the r^2 values, although one should look at the predicted weight in each age group to see if the fit is acceptable at each value of X. Different kinds of curves will have errors at different ages; it may be that a curve with a slightly lower r^2 value has a better fit for a more critical part of the curve,

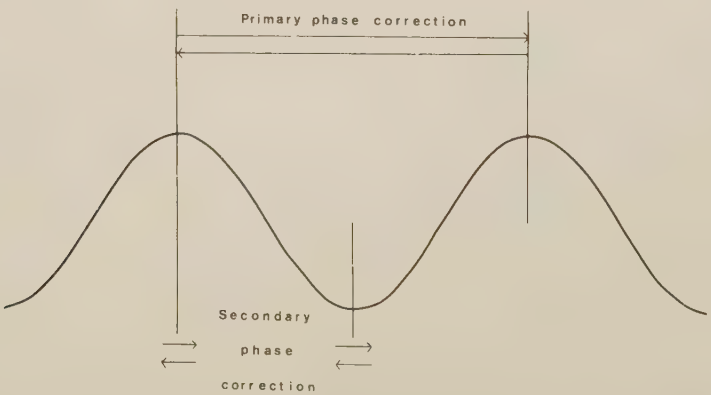

Figure 1. Primary phase corrections involve shifting the entire sine wave to coincide with the general pattern of maximum and minimum weights. Secondary phase corrections involve shifting wave maxima and minima to coincide with actual dates of weight maxima and minima.

such as that for the younger age groups which have more animals in a population.

The third step involves the derivation of sine expressions for calculating the trends from maximum to minimum to maximum weight during the annual cycle. The amplitude of the sine wave represents the difference between maximum and minimum weights through the annual cycle, or year. Since the sine wave has to reach a maximum at the time when weights are maximum and a minimum when weights are minimum, phase correction procedures are used. Shifting the entire sine wave until the wave maximum and minimum are close to the maximum and minimum weights is called "primary phase correction" and further shifts to synchronize the timing of the wave and weights are called "secondary phase correction" (Figure 1). The procedure for calculating these corrections, from Moen (1980), is as follows:

1. Determine the number of days from maximum to minimum weight
2. Subtract 182.5 from the answer to Item 1
3. Divide the answer from Item 2 by 2 to get the secondary phase correction (SEPC)
4. Add (sign considered) the answer from Item 3 to the Julian day (JDAY) for maximum weight to get the adjusted Julian day for maximum weight (AJDAY)
5. Determine the primary phase correction (PRPC) from the following formula

$$\sin(\text{AJDA})\ (0.9863) + \text{PRPC} = 1.0$$

Since $\sin 90 = 1.0$

$$\sin(\text{AJDA})\ (0.9863) + \text{PRPC} = 90$$

and $$\text{PRPC} = 90 - (\text{AJDA})\ (0.9863)$$

The Julian days for maximum and minimum weights and related phase corrections in the three regions are given in Table 1.

TABLE 1. JULIAN DAYS FOR MAXIMUM AND MINIMUM WEIGHTS AND RELATED PHASE CORRECTIONS FOR MALE AND FEMALE DEER IN THREE REGIONS OF NEW YORK

Region	Julian day		Phase correction	
	Maximum	Minimum	Primary	Secondary
Male				
Central Adirondacks	301	106	−200.71	− 6.25
Central New York and Southern Tier	301	106	−200.71	− 6.25
Central Catskills	301	106	−200.71	− 6.25
Female				
Central Adirondacks	301	121*	−208.11	+ 1.25
Central New York and Southern Tier	331	106*	−215.51	−21.25
Central Catskills	316	106*	−208.11	−13.75

*Early spring minimum; further reductions at parturition are described in text.

The fourth step involves the over-all equation for calculated live weight[2] in kilograms (CLWK) which may be expressed as follows:

$$CLWK = [MAWK + MIWK]/2 + \sin \left\{ (JDAY)\ (0.9863) + \left[\left(\sin \left\{ [(JDAY)\ (0.9863) + PRPC] + (SEPC) \right\} \right) SEPC \right) + PRPC \right] \right\} \cdot [MAWK - MIWK]/2$$

This equation is used to derive live weight from two independent variables, i.e., age in days and the Julian day for maximum weight. Adding together the maximum and minimum weights (MAWK and MIWK), i.e., Y and Y' as calculated by the equations in Steps 1 and 2, for a given Julian day (the first expression in brackets) and dividing the sum by 2 results in a midpoint weight for deer of the age represented by that day (AGDA). Note that AGDA is the independent variable for calculating MAWK and MIWK for a given JDAY and that 0.9863 is the ratio 360/365 for converting days to degrees.

The AGDA, as used in this paper, begins on a standardized birth date of June 1 (which is Julian day 152). This date is used for simplicity in calculation as it is unnecessary to use the estimated birth date of each deer. Therefore, a fawn has an AGDA of 213 days on December 31 (365 − 152 = 213). The following examples illustrate how a deer's age in days and the corresponding Julian day are matched for different age groups. A complete table can be made in this way.

Age group (years)	Age in days	Julian day
0 - 1	15	167
	214	1
	365	151
1 - 2	380	167
	579	1
	730	151
2 - 3	745	167
	944	1
	1095	151

[2]In this paper, the term "live weight" is used to represent the average weight of a healthy deer of a given age in a population or segment of a population. Calculation of live weight in this sense is different and more involved than converting field-dressed weight to live weight for individual specimens.

The sine expression between the first pair of braces is calculated next. This is then multiplied by one-half the difference between the maximum and minimum weight (the last expression in brackets) to get the sinusoidal deviation from the midpoint weight. This deviation is added to the midpoint weight as previously determined to derive the final calculated live weight for that date.

It is necessary to adjust the weights of females predicted with such equations for changes during gestation, parturition and lactation. The deviations depend on the mass and number of fetuses produced; they are considered under "results" where the over-all pattern is described.

The equations presented in this paper have been developed for deer weights given by Severinghaus and Gottlieb (1959) and Severinghaus (1979, 1980). Field-dressed weights were converted to live weights by using a factor given by Severinghaus (1949). Since hunting seasons at the time the data were recorded extended over a 3-month period (October through December) when deer were in a weight decline, maximum weights generally occurred prior to such seasons. Therefore, field-dressed weights were adjusted upward to calculated maximum weights. Regression equations (Moen, 1973), based on New Hampshire data reported by White (1968), were used to determine the average weight loss per week. All data were converted to kilograms by multiplying pounds by 0.4536.

Correct derivation of equations is dependent on the use of accurate weights and ages in curve fitting. Age was assigned as the number of elapsed days after an assumed Julian birth date of 152 (June 1). There is a tendency to underestimate the age of deer, thus ascribing younger ages to older deer with heavier weights, so that weights recorded in field data for a given age average greater than is actually the case. This occurs more frequently with respect to females than males because there are no antlers to assist in making decisions. The error was conspicuous when curve fitting the weights of female deer from Central New York and the Southern Tier and the Central Catskills, and average weights were adjusted for inaccuracies in aging by visual evaluation of the fitted curves. Adjusted weights are shown in Table 2. Their use represents the authors' best judgement in

TABLE 2. WEIGHT ADJUSTMENT TO COMPENSATE FOR UNDERESTIMATION OF AGE IN FIELD DATA, FOR DEER OF TWO AGE GROUPS IN TWO REGIONS OF NEW YORK

	Age group			
	2½ years		3½ years	
Region	Field weight	Adjusted weight	Field weight	Adjusted weight
Central New York and Southern Tier	68	58	69	64
Central Catskills	60	46	60	54

expressing maximum and minimum weights and weight changes through the year.

The procedures for expressing weights as continuous mathematical expressions are obviously not simple, but practice in each of the stages (Moen, 1980) enables one to derive good over-all equations for each sex. The methods apply to other species of wild ruminants too; curve fitting and phase adjustment can be adapted for any population.

RESULTS

Power curves best fit the data for male deer, and logarithmic curves those for female deer, for both maximum and minimum live weights and death weights in both exposed and sheltered areas. The values of a, b and r^2 are given in Table 3. Substituting these values of a and b, and those for PRPC and SEPC as given in Table 1, in the equation for live weight (CLWK), the weights of male and female deer have been calculated for 15-day intervals and are plotted for the Central Adirondacks (Figure 2), Central New York and the Southern Tier (Figure 3) and the Central Catskills (Figure 4).

An important biological deviation from the general pattern occurs for pregnant females. The weight of a pregnant female may be divided into two compartments: maternal tissue, and fetal plus associated reproductive tissues. As minimum weights are reached in April and gains begin when range conditions improve in May, the weights of females reflect an apparent gain as fetal and reproductive tissues increase and maternal tissue decreases. This apparent weight gain results when production is directed toward the growth of fetal and reproductive tissue during the last quarter of pregnancy.

Immediate weight losses occur at parturition when fetuses, fluids and other tissues are expelled (Robbins and Moen, 1975). These were subtracted from the total live weight at that time. After parturition, maternal weight levels off during the first part of the lactation period due to the high energy cost of milk production (Moen, 1973), followed by weight gains as milk production decreases in the last two-thirds of lactation, and the deer reach maximum weight again in November and December.

Two variables affect the mass of fetal and reproductive tissue at parturition: the number of fetuses and the fetal mass. Equations were derived for these by Moen (1980). Predicted weights of fetuses and of fetuses plus the associated reproductive tissues for different fetal weights at birth, as used to estimate the reproductive component of the total weight of a female during the last 120 days of gestation, are given in Table 4.

Expected weights of the females, minus fetal and reproductive tissues, are indicated in Figure 5 as dotted lines. Weight curves for females in the Central Adirondacks, bred at 1½ years and giving birth to single fawns (characteristic of 95 per cent of this age group in that region) weighing 2.5 kilograms, are shown in part A. Weight curves in part B are for females in Central New York and the Southern Tier, bred at 1½ years and giving

TABLE 3. VALUES OF FACTORS USED IN EQUATIONS FOR CALCULATING SEASONAL WEIGHT CURVES AND DEGREE OF CORRELATION FOR MALE AND FEMALE DEER IN THREE REGIONS OF NEW YORK

Region	Curve		Factor		Correlation (r^2)
	Definition	Type	a	b	
Male					
Central Adirondacks	Maximum live weight	Power	3.13	0.45958	1.00
	Minimum live weight	Power	0.99	0.55035	0.99
	Death weight-exposed	Power	1.32	0.50554	1.00
	Death weight-sheltered	Power	1.09	0.50650	1.00
Central New York and Southern Tier	Maximum live weight	Power	6.24	0.38906	1.00
	Minimum live weight	Power	2.23	0.47800	0.99
	Death weight-exposed	Power	1.44	0.50024	0.97
	Death weight-sheltered	Power	1.46	0.46902	0.98
Central Catskills	Maximum live weight	Power	3.36	0.45233	1.00
	Minimum live weight	Power	0.79	0.58830	0.99
	Death weight-exposed	Power	1.70	0.47036	0.99
	Death weight-sheltered	Power	1.41	0.47122	0.99
Female					
Central Adirondacks	Maximum live weight	Logarithmic	−23.40	10.97253	0.97
	Minimum live weight	Logarithmic	−28.85	9.23499	0.95
	Death weight-exposed	Logarithmic	−43.24	11.66182	0.93
	Death weight-sheltered	Logarithmic	−36.10	9.72584	0.93
Central New York and Southern Tier	Maximum live weight	Logarithmic	−24.23	12.80383	0.99
	Minimum live weight	Logarithmic	−33.88	11.75924	0.87
	Death weight-exposed	Logarithmic	−25.69	8.83499	0.87
	Death weight-sheltered	Logarithmic	−25.53	7.96984	0.87
Central Catskills	Maximum live weight	Logarithmic	−38.05	13.35857	0.99
	Minimum live weight	Logarithmic	−47.66	12.25631	0.89
	Death weight-exposed	Logarithmic	−47.74	12.31377	0.98
	Death weight-sheltered	Logarithmic	−39.85	10.27433	0.98

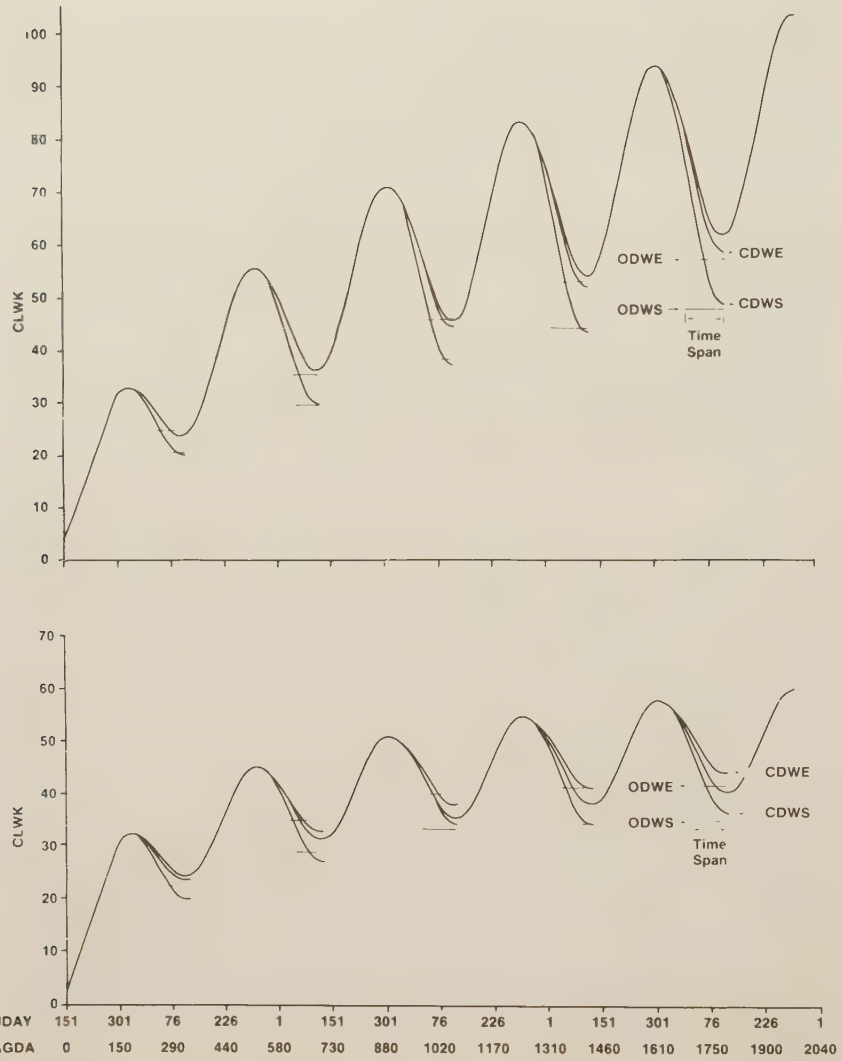

Figure 2. Male (above) and female (below) deer in the Central Adirondacks: curves for maximum and minimum average live weights, together with those for death weights in exposed areas and in sheltered areas, as well as the time span in the winter when death occurs in both exposed and sheltered areas. For male fawns and yearlings the death weight curves were virtually identical with those for live weight.

birth to single fawns (characteristic of about two-thirds of the females in this age group) weighing 3.5 kilograms and twins (characteristic of about one-third of the females in this age group) each weighing 3.0 kilograms. Weight curves in part C are for females in the Central Adirondacks, bred at 3½ years and giving birth to single fawns (characteristic of just over half

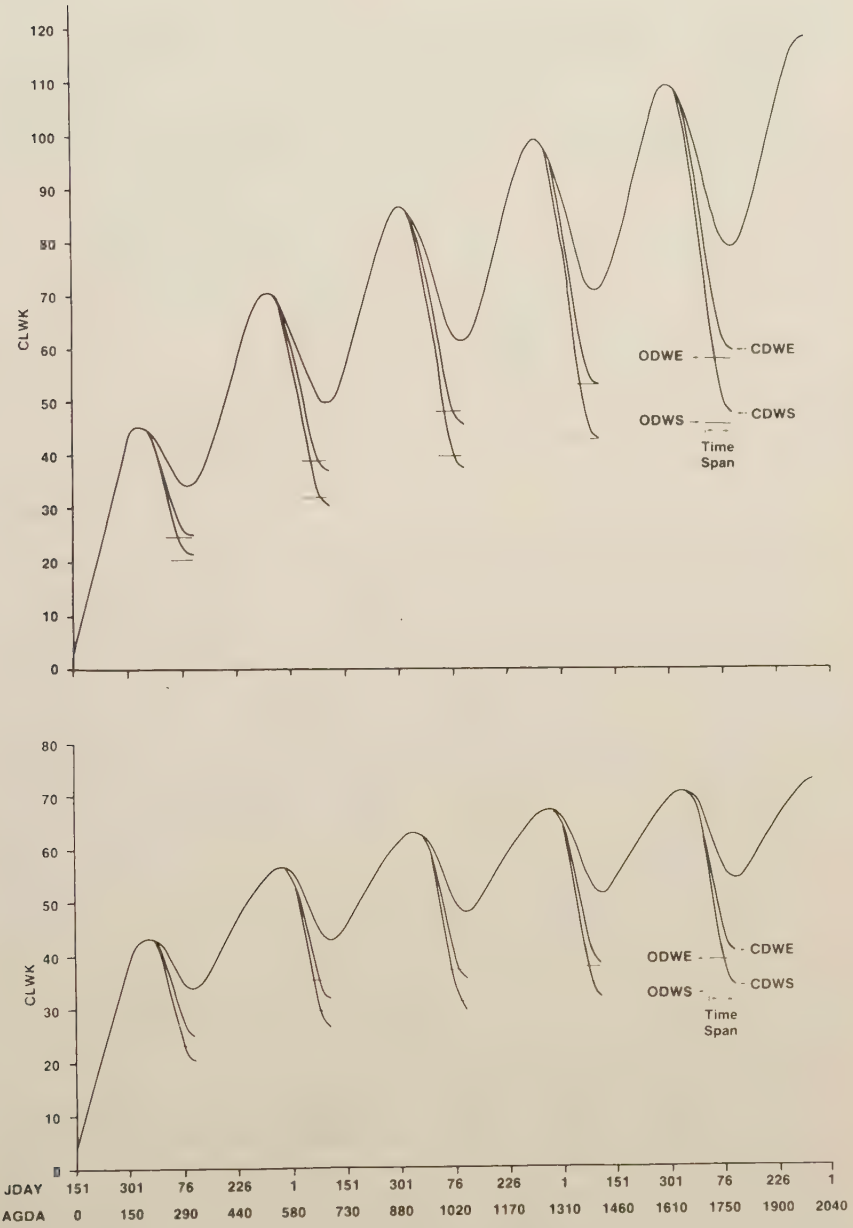

Figure 3. Male (above) and female (below) deer in Central New York and the Southern Tier: curves for maximum and minimum average live weights, together with those for death weights in exposed areas and in sheltered areas, as well as the time span in the winter when death occurs in both exposed and sheltered areas.

the females in this age group) weighing 3 kilograms and twins (characteristic of nearly all the females in this age group) each weighing 2.5

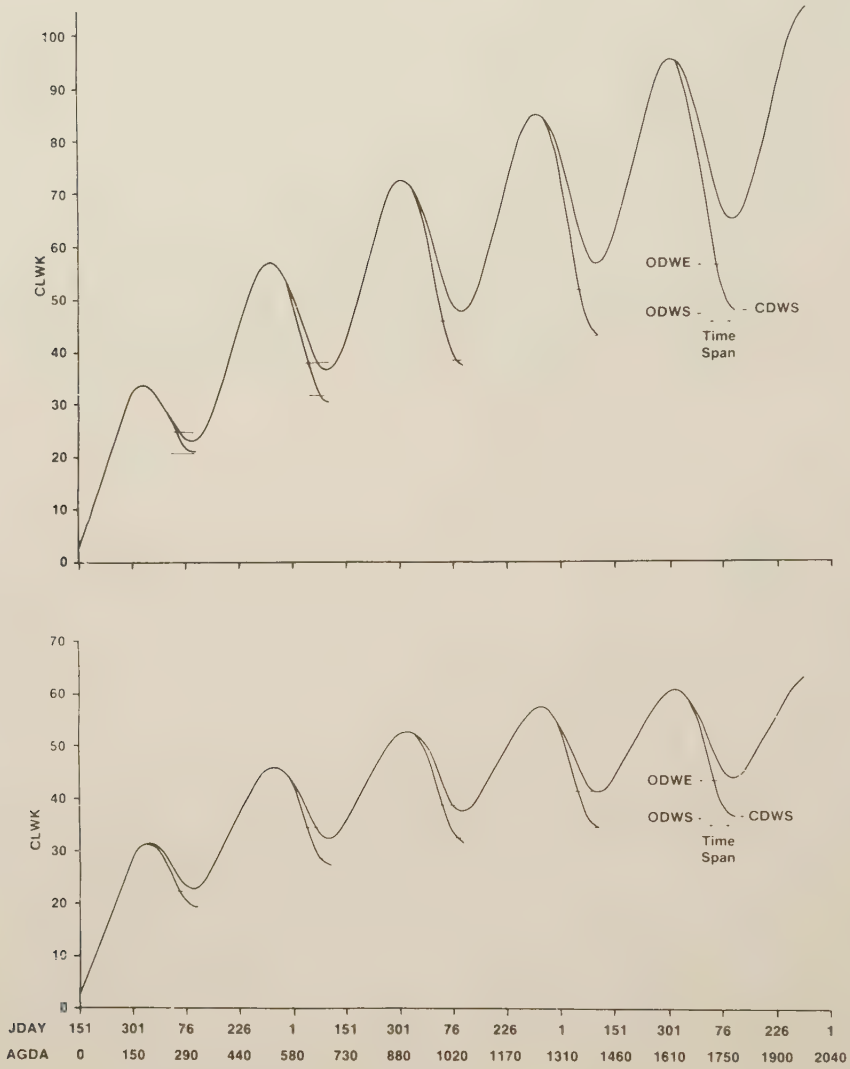

Figure 4. Male (above) and female (below) deer in the Central Catskills: curves for maximum and minimum average live weights, together with those for death weights in sheltered areas. Curves for death weights in exposed areas approximated those for live weight too closely to be plotted separately.

kilograms each. Weight curves in part D are for females in Central New York and the Southern Tier, bred at 3½ years and giving birth to twins (characteristic of nearly all the females in this age group) each weighing 3.5 kilograms. Recovery of body weight after parturition must occur very rapidly as maximum levels in the fall are reached in late October and November. The pattern of weight gain after parturition connects to documented fall maximums.

TABLE 4. PREDICTED WEIGHTS OF FETUS (UPPER VALUE) AND OF FETUS PLUS ASSOCIATED REPRODUCTIVE TISSUES (LOWER VALUE) FOR FETUSES OF DIFFERENT WEIGHTS AT BIRTH, ACCORDING TO DAYS OF GESTATION*

Weight of fetus at birth	Days of gestation								
	80	95	110	125	140	155	170	185	200
2.0	0.06	0.12	0.21	0.34	0.52	0.76	1.08	1.49	2.00
	0.69	0.78	0.91	1.10	1.35	1.68	2.11	2.65	3.34
2.5	0.08	0.15	0.26	0.42	0.64	0.95	1.35	1.86	2.50
	0.73	0.85	1.01	1.24	1.55	1.96	2.50	3.19	4.05
3.0	0.09	0.17	0.30	0.49	0.76	1.12	1.61	2.22	3.00
	0.78	0.91	1.10	1.38	1.75	2.24	2.89	3.72	4.76
3.5	0.10	0.20	0.34	0.57	0.88	1.30	1.86	2.59	3.50
	0.82	0.98	1.20	1.52	1.95	2.53	3.28	4.25	5.47
4.0	0.11	0.22	0.39	0.64	0.99	1.48	2.12	2.95	4.00
	0.86	1.04	1.29	1.65	2.15	2.81	3.67	4.78	6.18

*All weight data in kilograms.

DISCUSSION

Seasonal fluctuations are characteristic of the species, but differences in the weight curves for deer from different regions of the State demonstrate the dependence of deer on adequate nutrition. Deer in the Central Adirondacks weigh the least and those in Central New York and the Southern Tier the most, while those in the Catskills are in between. In the Central Adirondacks, when twins (average weight 2.5 kilograms) are born, the average weight of females at parturition approaches or even falls below the observed death weights for sheltered areas. Twins are likely to be borne only by heavier-than-average females that would be above the average weight throughout the annual cycle. The narrow range between observed and calculated death weights for fawns living in exposed areas (22.2 to 23.2 kilograms for females and 24.0 to 25.0 kilograms for males) and in sheltered areas (18.0 to 19.0 kilograms for females and 20.0 to 21.0 kilograms for males) suggest that three biological functions are operating. One, metabolism cannot keep up with heat loss from deer in exposed areas as well as in sheltered areas, so higher death weights are observed in exposed areas than in sheltered areas. Death is due to local, transient thermal conditions that cause hypothermia. Two, there is a lower limit to the body mass at which death occurs, regardless of the fawn's condition going into the winter, since they die at very similar weights in all three regions of the State. Three, death weights of females are lower than those of males; females are smaller at the beginning of winter too.

The minimum winter and maximum fall live weights are much more variable in these three regions than are the death weights. For male fawns, calculated minimum winter live weights are 23.4, 34.8 and 23.3 kilograms for the Central Adirondacks, Central New York and the Southern Tier and the Central Catskills, respectively. These are nearly equally proportional to

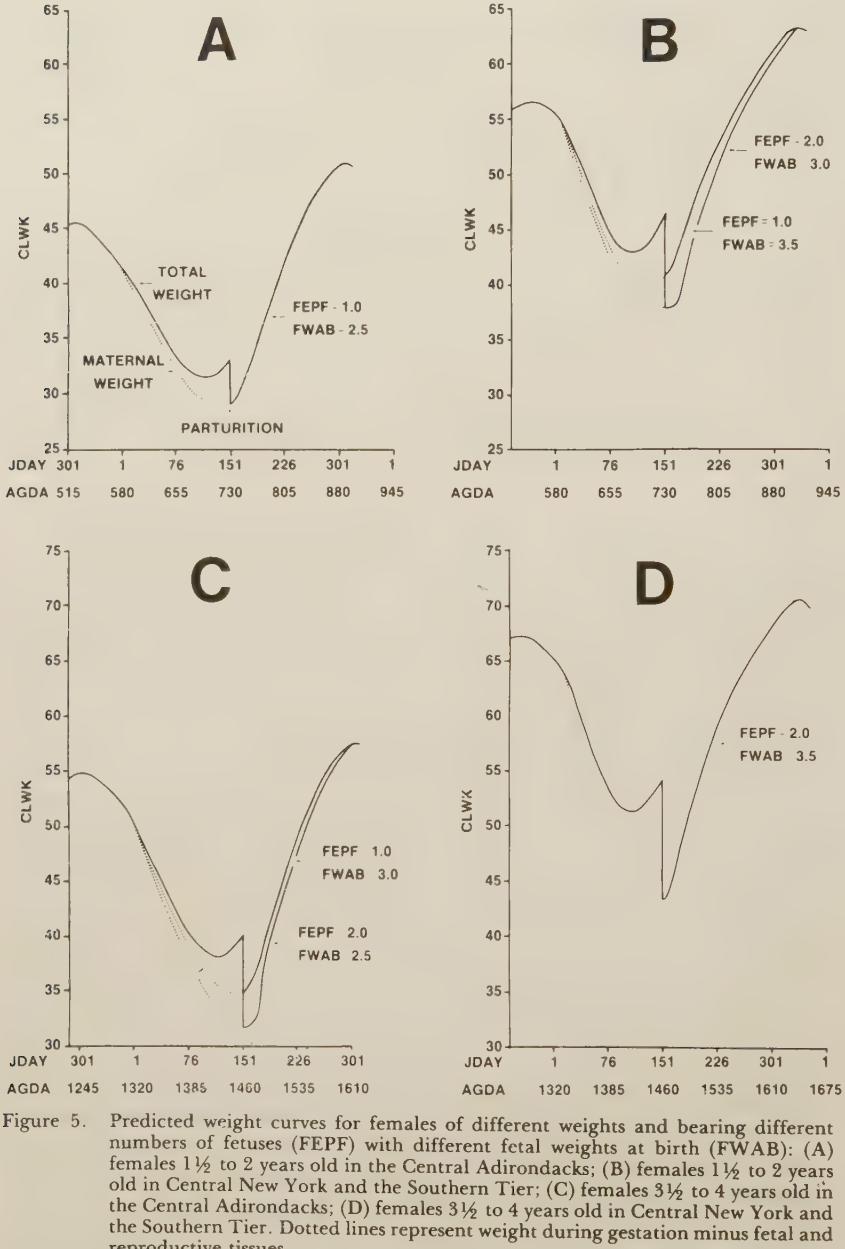

Figure 5. Predicted weight curves for females of different weights and bearing different numbers of fetuses (FEPF) with different fetal weights at birth (FWAB): (A) females 1½ to 2 years old in the Central Adirondacks; (B) females 1½ to 2 years old in Central New York and the Southern Tier; (C) females 3½ to 4 years old in the Central Adirondacks; (D) females 3½ to 4 years old in Central New York and the Southern Tier. Dotted lines represent weight during gestation minus fetal and reproductive tissues.

the corresponding calculated maximum fall weights of 32.9, 45.7 and 33.9 kilograms, the ratios being 0.71, 0.76 and 0.69, respectively. For female fawns in the three regions, the calculated minimum winter live weights are

24.7, 34.0 and 22.9 kilograms, respectively, and the corresponding maximum fall weights are 32.7, 43.1 and 31.3 kilograms. The ratios between these values (0.76, 0.79 and 0.73) are nearly equal. The calculated minimum winter and maximum fall live weights for older age groups show similar patterns, with both male and female deer in the Central Adirondacks and Central Catskills being much smaller than those in Central New York and the Southern Tier.

These relationships can be further extended to approximate the weights-of-no-return for all ages and both sexes. These weights must be below minimum winter live weights and above death weights in sheltered areas on the winter range. For example, the minimum winter live weight of male fawns in the Central Adirondacks is about 23.9 kilograms, and the sheltered area death weight is between 20.0 and 21.0 kilograms. A weight-of-no-return for male fawns in a sheltered area should be between 23 and 21 kilograms. Female fawns under similar conditions should have an approximate weight-of-no-return between 23 and 19 kilograms. Estimated weights-of-no-return for all ages and both sexes are tabulated in Table 5; survival and recovery from winter weights below these is unlikely.

Weight patterns through the annual cycle are very helpful in explaining the occurrence of winter losses. Ratios of maximum fall weight to weight-of-no-return for deer of both sexes in five age groups for the three regions are listed in Table 6. Note that in the Central Adirondacks and Central Catskills, where they average smaller than elsewhere, fawns are closer to the weight-of-no-return (ratio = 1.5) when winter begins and therefore have a much smaller safety margin than the larger fawns in Central New York and the Southern Tier (ratio = 2.1 for males and 2.0 for females).

TABLE 5. WEIGHT-OF-NO-RETURN (I.E., ESTIMATED WINTER WEIGHT FROM WHICH RECOVERY IS IMPOSSIBLE) FOR DEER IN NEW YORK, ACCORDING TO SEX AND AGE GROUP*

Sex	Age group				
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5
Male	22	33	42	49	54
Female	21	30	35	36	38

*Data in kilograms; same weights apply to all three regions studied.

TABLE 6. RATIOS OF MAXIMUM FALL WEIGHT TO WEIGHT-OF-NO-RETURN FOR MALE AND FEMALE DEER IN THREE REGIONS OF NEW YORK, ACCORDING TO AGE GROUP

Region	Age group				
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5
Male					
Central Adirondacks	1.5	1.7	1.7	1.7	1.7
Central New York and Southern Tier	2.1	2.2	2.1	2.0	2.0
Central Catskills	1.5	1.7	1.7	1.7	1.8
Female					
Central Adirondacks	1.5	1.5	1.4	1.5	1.5
Central New York and Southern Tier	2.0	1.9	1.8	1.9	1.9
Central Catskills	1.5	1.5	1.5	1.6	1.6

The benefits of higher fall maximum weights are illustrated by the body-composition analyses of Robbins et al. (1974). In the Central Adirondacks, a 33.0-kilogram male fawn with an ingesta-free weight of 29.7 kilograms should contain about 2.0 kilograms of fat, representing 6.7 per cent of its ingesta-free weight. In Central New York and the Southern Tier, a 45.7-kilogram male fawn with an ingesta-free weight of 41.1 kilograms contains about 4.3 kilograms of fat, representing 10.5 per cent of its ingesta-free weight. The lesser fat reserve, both in mass and relative to ingesta-free weight, of the smaller Adirondack fawns results in earlier death as their energy reserves are depleted sooner than those of the larger fawns in the other regions. Mortality is expected in the Adirondacks and Catskills under harsh winter conditions, since the average winter live weights of deer in their first winter are very close to the observed death weights. In fact, overwinter losses among the smallest (probably youngest) fawns can be expected almost every year.

Higher average death weights of deer in exposed areas in the Adirondacks suggest that survival in such areas by deer with a small fat reserve is virtually impossible. Females have only a slight chance of survival, and only the prime-age males have sufficient body mass to winter in the more exposed areas in the Central Adirondacks and Central Catskills. Areas with heavy coniferous cover and suitable topography provide a better chance for overwinter survival of deer, enhancing the energy conservation adaptations described by Moen (1976, 1978).

Death weights are lower in sheltered areas than in exposed areas. Extending this relationship, they should be lower in climates more moderate than that of New York, and higher where the climate is more severe. It must be recognized, however, that thermal energy does not function as energy for metabolic processes; warmer days only reduce the thermal gradient between animal and environment, reducing heat loss. Energy from food and stored fat is necessary to drive metabolic processes. Survival is dependent on delicate balances between the effects of shelter on current thermal conditions in relation to ecological metabolism, the energetic effects of accumulated snow, and the nutritive characteristics of the range.

While the safety margin for larger fawns is greater and their chances of survival better, conditions can occur that are too energetically costly for life to continue. Fawns were found dead in Central New York and the Southern Tier in the spring of 1978 after an unusually long period of deep snow. In the same way that severe local, transient thermal conditions can cause death when metabolism cannot keep up with heat loss, deep snow makes movement so costly that animals are forced to live on fat reserves or face exhaustion from the effects of snow as a mechanical barrier.

These expressions of age-weight relationships for deer as continuous functions through time may be adapted to any species exhibiting one maximum and one minimum weight through each annual cycle. The equation for estimating the weight of fetal and reproductive tissue may be modified

for use as a first approximation for other ruminants, proportional to the length of the gestation period and fetal weight at birth. Such expressions of age-weight relationships and comparisons of weights of deer from different areas offer significant opportunities for evaluating population dynamics because natality and mortality rates are known to be weight-related biological functions. Population analyses are commonly based on sex and age structures, but weight and metabolic structures may be of much greater value for such analyses. The derivation of equations for expressing seasonal differences in weight over successive annual cycles is a fundamental step in understanding the ecology of an animal, especially a large mammal.

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THE WARMWATER SPORT FISHERY OF EASTERN LAKE ONTARIO

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ABSTRACT

A creel census was carried on from June 17 to October 27 in 1978 in the New York waters of eastern Lake Ontario to determine the extent and distribution of fishing effort and harvest. A total of 1,676 counts of shore anglers and boats were recorded, and 372 anglers were interviewed. Fishing pressure was estimated as 274,073 angler hours (± 5 per cent) with 91 per cent of it being associated with the boat fishery and 55 per cent done on weekends and holidays. The estimated total harvest of 394,529 fish included 13 species, of which smallmouth bass, yellow perch and rock bass comprised 98 per cent. Catch rates for legal-sized smallmouth bass averaged 0.47 fish per hour in the boat fishery. Catch rates were similar to those of earlier studies indicating that the bass fishery in the eastern basin is both stable and of high quality

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A major informational gap for Lake Ontario fisheries has been a lack of detailed lakewide assessments of sport fishing effort and harvest. Need for such data for the Great Lakes has been clearly recognized, particularly where management of both sport and commercial fisheries is required.

Since salmonid stocking in Lake Ontario was begun in 1968 by the New York State Conservation Department and the Ontario Ministry of Natural Resources, interest in the lake's sport fisheries has grown to unprecedented levels. Assessment of fishing effort and harvest has been sporadic and limited to specific fisheries, e.g., Jolliff and LeTendre (1967), Brown (1976), and Farr and Blake (1979). Although useful in describing local conditions, these studies do not provide sufficient data for evaluating total user participation and harvest. Consequently, the Department undertook major creel census projects on Lake Ontario in 1978 to provide such data as well as information on the socio-economic characteristics of the fishermen.

Stone et al. (1951) ranked the eastern basin of Lake Ontario as the most productive area for smallmouth bass in New York State and noted its long reputation for excellent warmwater sport fisheries. Stocks of smallmouth bass have remained stable and abundant with no major changes in recent years (Christie, 1973). In addition to indicating smallmouth bass (*Micropterus dolomieu*) to be the most important species in terms of angler preference, economics and catch, Jolliff and LeTendre (1967) noted that other warmwater species, such as northern pike (*Esox lucius*), yellow perch (*Perca flavescens*) and rock bass (*Ambloplites rupestris*), were also significant. The present paper summarizes findings of a creel census in New York waters of the eastern basin.

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METHODS

The study area comprised the waters of eastern Lake Ontario (excluding tributaries) from Stony Point to Tibbets Point (Figure 1). The census consisted of counting the number of anglers and interviewing some of them for specific information. It was conducted on 78 days between June 17 and October 27 in 1978. To increase the statistical reliability of estimates of fishing pressure, censuses were stratified by weekday and weekend-holiday

Figure 1. Location of study area (within dash line) in the eastern basin of Lake Ontario.

periods (i.e., day type), and by whether an angler was fishing from the shore or a boat (i.e., fishing type). All weekend days and holidays, as well as two weekdays per week, were selected for sampling. Since the effective fishing day was approximately 14 hours, and creel census agents worked an 8-hour day, each survey day consisted of a morning or an afternoon period of 6½ hours, i.e., from 6:30 a.m. to 1:00 p.m. or from 1:00 p.m. to 7:30 p.m. Morning and afternoon periods were randomly assigned within each day-type stratum.

Within the study area, 16 sampling stations were selected on the basis of their suitability for obtaining reliable counts of shore anglers and boat anglers (Figure 2). Stations 1 to 6 represented the section between Stony Point and Pillar Point, and Stations 7 to 16 represented the section between Pillar Point and Tibbets Point. Because of their size (ca. 150 square miles) and limited personnel, the two sections were censused on alternate days within each day-type stratum.

At each sampling station, counts of shore anglers and boats (including the number of anglers per boat) were made by observations either from shore or from a roving boat. Half of the total sampling was done by each of these counting techniques through assigning them to alternate days within the two day-type strata in each section of the study area. Poor weather con-

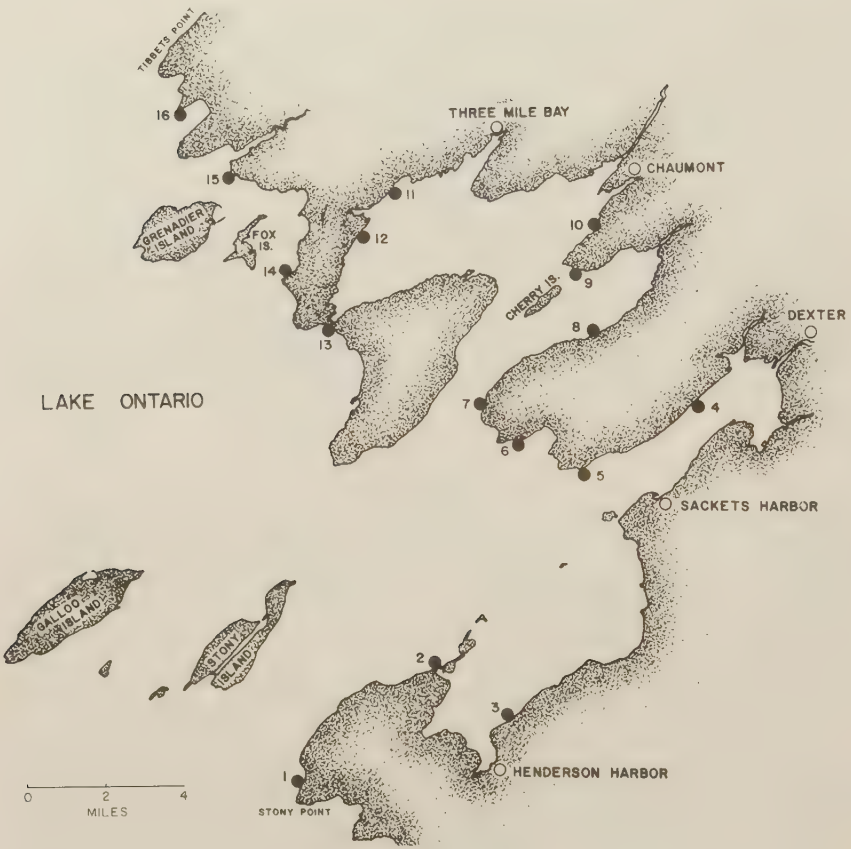

Figure 2. Location of sampling stations in the study area.

ditions often precluded censusing by boat, and in these instances an instantaneous shore count was substituted at each station.

Because the sampling stations were selected on the basis of their suitability for making counts from the shore, it was often difficult to identify them from the boat. To minimize variation and bias between the two counting methods, it was necessary to define geographic boundaries for each site. Because the counts from shore and those by boat were made on alternate days, both were made by the same personnel, and it was possible to standardize the site boundaries so that overlap in boat counts between adjacent sites was minimal.

Due to the large area to be censused each day, it was impractical to set random starting sites. Census personnel began work at either end of the section to be covered, alternating starting points with day-type strata. The roving boat crew started from public boat-launching sites at Henderson

Harbor for the section between Stony Point and Pillar Point, and at Chaumont Bay for the section between Pillar Point and Tibbets Point.

Angler interviews were intended to provide data on the total catch and harvest as well as on angler origins and trip expenditures. In designing the census, it was decided that the number of interviews of shore anglers and that of boat anglers should be proportional to the daily observations of fishing pressure for each group.

Since the presence of numerous private launches limited the probability of obtaining boat-angler interviews at public boat-launching sites, interviews by the roving boat crew provided the basis for estimating their total catch and harvest. Such interviews generally introduce bias since they rarely involve a completed fishing trip. To compensate for this, shore-based interviews were made on alternate days within the sampling strata.

Socio-economic data were of lower priority than data on fishing and were collected only as time permitted. They included the state and county of residence, purpose of trip, duration of trip and trip expenditures. Costs per angler day were calculated separately for shore anglers and boat anglers and were expanded by the estimated total number of trips by each group to provide an approximation of the economic significance of the fishery.

All data were recorded on standard forms designed for direct keypunching. They were edited for accuracy and later keypunched by a commercial computer service. The data were analyzed by using the Statistical Package for Social Services, batch version (SPSS8), as available through the Univac 1100 operating facility at the State University at Albany.

RESULTS

The findings are presented separately for the major aspects of the fishery.

FISHING PRESSURE

For expansion purposes, the data for each month were treated as an independent sample and were further subdivided according to day-type and fishing-type strata. A fishing pressure estimator, $\bar{y}$ (k), in which

y = number of boats or shore anglers

k = number of observations within fishery and day-type strata

and which reflected the mean count per station, was developed for shore anglers and for boats, within each day type, by using SPSS procedures (Nie et al., 1975). Within-stratum estimates of the total number of shore-angler hours were made by assuming that a fishing day was 14 hours long and

then expanding the estimator value by the constant (K) as derived from the equation $K = N \cdot s \cdot t$ in which

N = number of stations

s = hours per fishing day (i.e., 14)

t = number of days spent in stratum during survey period

To estimate boat-angler hours, the corresponding estimator value for boat hours was expanded by the mean number of fishermen per boat in addition to the K value. Except for the estimator value, each of these parameters was treated as a constant.

A total of 16,676 counts of shore anglers and boats were recorded. For each group the total estimated angler hours for each month and day type are shown in Table 1. The degree of precision (± 2 standard errors) associated with the estimate of total fishing pressure (i.e., 274,073 angler hours ± 5 per cent) was high. Precision for the monthly estimates was

Table 1. Estimated Total Hours Fished in the Study Area Each Month By Boat Anglers and Shore Anglers According to Day Type*

Month	Weekend-holiday		Weekday	
	Boat anglers	Shore anglers	Boat anglers	Shore anglers
June	16,991 (28.4)	494 (28.6)	7,903 (29.4)	1,737 (28.6)
July	42,159 (18.8)	2,242 (18.2)	47,256 (21.2)	4,706 (20.2)
August	41,030 (20.8)	1,027 (20.4)	43,564 (18.4)	2,114 (18.4)
September	38,433 (20.8)	819 (20.8)	6,110 (22.4)	2,568 (22.4)
October	6,149 (32.4)	194 (32.4)	8,456 (23.2)	121 (23.2)
Total	144,762 (10.2)	4,776 (10.0)	113,289 (9.4)	11,246 (9.8)
Aggregate		274,073 (5.0)		

*Figures in parentheses are confidence limits as percentages representing ± two standard errors.

lower, ranging from 18.4 to 32.4 per cent (mean = 14.3) in the boat fishery and from 18.2 to 32.4 per cent (mean = 22.3) in the shore fishery. Lower precision was undoubtedly related to smaller sample sizes. Boat angling accounted for 97 per cent of the weekend and 91 per cent of the weekday fishing pressure. The contribution of shore angling to the total fishing pressure was generally insignificant (less than 6 per cent).

Distribution of fishing pressure by fishing type was determined from the mean census counts and observations during airplane flights. During the study, the Department's Bureau of Aviation made 21 counts of boat and shore anglers within the study area. By combining the census counts with the general distribution patterns obtained from aerial observation, it was possible to identify areas of heavy, moderate and light fishing pressure (Figure 3). The heaviest boat-fishing pressure (more than 10 boats per station) occurred in the Henderson Harbor-Association Island area and along Fox and Grenadier Islands. Moderate activity (5-10 boats per station) occurred in Wilson Bay, off Point Peninsula Isthmus, along Pillar Point, east

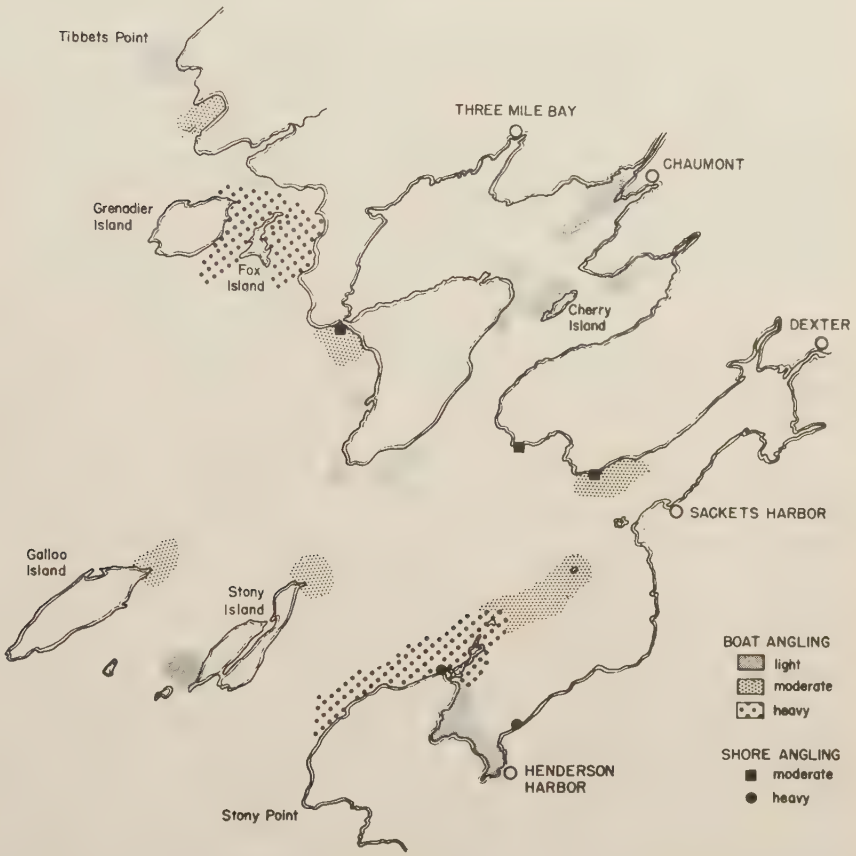

Figure 3. Distribution of fishing pressure in the study area from June through October in 1978, for boat angling and shore angling.

of Association Island and along the northeastern shores of Stony and Galloo Islands. Shore-fishing activity of more than one angler per station occurred at Stations 2 and 3 in Henderson Harbor, while moderate activity (0.4-1.0 angler per station) occurred at Stations 5 and 6 along Pillar Point and at the Point Peninsula Isthmus (Station 13). Shore-fishing was associated with availability of sites and ease of access. The most readily available site in the study area was at the bridge or "Cut" connecting Henderson and Association Island (Station 2). This locality consistently maintained the highest shore-fishing activity and was the most commonly used shore-access site.

Daily distributions of fishing pressure within fishing-type and day-type strata had bimodal patterns. Boat-angling pressure peaked at 2:00 p.m. on the weekends and at 3:00 p.m. on weekdays. Secondary peaks within both day strata occurred during the morning at 9:00 a.m. Afternoon peaks

Table 2. Estimated Total Catch and Harvest By Species in the Study Area From June 17 to October 27 in 1978

Species	Number harvested						Number caught	Percentage harvested
	June	July	August	September	October	Total		
Smallmouth bass	10,906	127,706	25,999	15,720	2,993	183,324	343,442	53.4
Rock bass	11,353	75,113	8,876	347	. .	95,689	190,635	50.2
Yellow perch	9,359	68,693	21.396	7,654	652	107,754	144,653	74.5
White perch	328	3,526	. .	. .	. .	3.854	7,376	52.3
Largemouth bass	329	1,864	135	. .	. .	2,328	6,187	37.6
Pumpkinseed	. .	. .	165	. .	. .	165	1,220	13.5
Brown bullhead	17	441	88	. .	. .	546	766	71.3
Black crappie	. .	. .	265	. .	. .	265	706	37.5
Lake trout	. .	176	. .	60	. .	236	236	100.0
Channel catfish	177	. .	. .	. .	. .	177	177	100.0
White bass	. .	. .	88	. .	. .	88	88	100.0
Walleye	. .	. .	88	. .	. .	88	88.	100.0
Brown trout	. .	. .	. .	. .	15	15	15	100.0
Unidentified	. .	. .	. .	. .	. .	. .	135	0.0
Total	32.469	277,519	57,100	23,781	3,660	394,529	695,724	56.7

were consistently greater than morning peaks. Shore-fishing activity parallelled that of the boat fishery.

CATCH AND HARVEST

Of the fish caught, some were not kept by the angler (i.e., were not harvested) because they were less than the legal size or not considered desirable. Estimates of the total catch and harvest, as well as their species composition, were derived from 372 angler interviews. The 293 boat and 79 shore interviews were roughly proportional to the fishing pressure for the two groups. The estimates were made for shore anglers and boat anglers separately by calculating the mean catch or harvest per angler hour for each species within each day-type stratum and then multiplying this value by the corresponding estimate of total hours fished. Aggregate figures were obtained by summing those for the several strata.

An estimated 702,502 fish were caught by anglers in the study area, of which 334,525 (56 per cent) representing 13 species were harvested (Table 2). The data clearly indicated the importance of smallmouth bass, yellow perch and rock bass, the combined harvest of which accounted for over 98 per cent of the total harvest. Other species were not significant in the harvest.

The relationship of harvest to total catch for a species often reflects a combination of biological and social factors which may include seasonal variations in fishing pressure, angler preferences and fishing regulations. As indicated in Table 3, the majority of anglers in the study area sought

TABLE 3. SPECIES PREFERENCES AS EXPRESSED BY ANGLERS INTERVIEWED IN THE STUDY AREA

Species	Preference*
Smallmouth bass	52.0
Yellow perch	13.8
Largemouth bass	9.6
Rock bass	2.0
Lake Trout	1.4
Channel catfish	1.1
Brown trout	0.6
Rainbow trout	0.2
No preference	19.3
Total	100.0

*Percentage of 372 anglers interviewed.

smallmouth bass and yellow perch. Preferences for other species were relatively low, although 19 per cent of the anglers expressed no preference. However, while anglers did not express a high preference for them during interviews, the data suggest a high rate of harvest for some of the implied "non-preferred" species. Species for which all fish caught were kept by the angler included brown trout, lake trout, walleye, channel catfish and white perch (Table 2). Harvest rates were also high for yellow perch, brown bullheads and rock bass.

Catch Rates and Angling Success

Catch per hour is a common measure of fishing success and has been used extensively in evaluating and comparing sport fisheries. Catch rates for the major species in the study area were summarized for each month according to fishing type and day type (Table 4). The values for small-

Table 4. Catch Per Hour Each Month For the Three Species Most Frequently Caught in the Study Area According to Fishing Type and Day Type

Species	Month	Boat anglers		Shore anglers	
		Weekend*	Weekday	Weekend*	Weekday
Smallmouth bass§	June	0.45	0.34	0.23	0.29
	July	0.76	0.75	0.32	1.37
	August	0.43	0.19	. .	0.01
	September	0.40	. .	0.29	0.04
	October	. .	0.46	. .	. .
	Mean	0.51	0.44	0.28	0.43
Rock bass†	June	0.46	1.01	0.36	1.09
	July	2.40	0.51	0.35	0.21
	August	0.36	0.42	0.27	0.17
	September	0.06	. .	0.29	. .
	October	. .	. .	. .	. .
	Mean	0.83	0.65	0.32	0.49
Yellow perch†	June	0.40	0.73	0.60	0.08
	July	1.24	0.23	0.16	0.45
	August	0.52	0.32	0.06	0.37
	September	0.22	. .	1.27	0.88
	October	. .	. .	0.12	. .
	Mean	0.59	0.43	0.44	0.45

*Includes holidays.
§Legal-sized fish only (12-inch minimum).
†All fish caught.

mouth bass represent only legally harvestable fish (i.e., 12 inches or more in length), while those for rock bass and yellow perch represent the total catch. Regardless of species, it was apparent that boat fishermen were more successful than shore fishermen in catching fish. Over-all angling success for all species was highest in July and declined thereafter throughout the summer and into the fall.

Catch rates of legal-sized smallmouth bass averaged 0.47 and 0.35 fish per hour for boat fishermen and shore fishermen, respectively. The highest rates for both types of fishing occurred in July when boat fishermen averaged 0.75 fish per hour and shore fishermen 0.85 fish per hour. The best bass fishing areas included Fox and Grenadier Islands (0.68), Henderson Harbor at Association Island (0.49) and along the high banks from Henderson to Stony Point (0.56).

For yellow perch, the second most frequently caught species, the average catch rate for boat fishermen was 0.51 fish per hour and that for shore fishermen was 0.44 fish per hour. The most productive areas included the Point Peninsula Isthmus (4.33), Fox and Grenadier Islands (1.77),

Henderson Harbor (1.52), Wilson Bay (1.32) and off Cherry Island in Chaumont Bay (1.29).

Rock bass, the third major warmwater species harvested in the study area, exhibited the highest average catch rates, 0.74 fish per hour for boat fishermen and 0.41 fish per hour for shore fishermen. The best boat fishing occurred in July when anglers caught 2.42 rock bass per hour. Shore fishermen were generally most successful early in the season and generally had more consistent success than boat fishermen. The most productive areas included Pillar Point (2.87), Henderson Harbor (1.07), Fox and Grenadier Islands (0.58) and Wilson Bay (0.47).

Catches of other species were not significant and were distributed throughout the study area. With a developing salmonid fishery and all indications suggesting restoration of a walleye fishery, some general observations on the locations of these catches may have future historic value. Brown trout and lake trout were reported along the high banks between Henderson and Stony Point. The only other reported catches of salmonids occurred at Stony and Galloo Islands and in the Black River below Dexter Falls. Occasional walleye catches were reported from Mud Bay and Grenadier Island.

ANGLER CHARACTERISTICS

In addition to data on fishing effort and catch, socio-economic data were collected from 304 anglers. Of these, 96 per cent were residents of New York State, the majority of whom lived in the counties of Jefferson, Onondaga and Monroe (Table 5). In total, anglers from 25 New York counties travelled to Jefferson County to fish in the eastern basin of Lake Ontario. Fishing by out-of-state residents was minimal (4 per cent) with most of them coming from Pennsylvania.

Angler expenditures, or "out-of-pocket costs" for gas, food, bait, etc., averaged $17.65 per individual per trip for boat fishermen and $12.54 for

TABLE 5. DISTRIBUTION BY COUNTY OF RESIDENCE OF ANGLERS INTERVIEWED IN THE STUDY AREA WHO WERE RESIDENTS OF NEW YORK STATE

County of residence	Proportion (per cent)	County of residence	Proportion (per cent)
Jefferson	31.3	Delaware	0.3
Monroe	22.0	Essex	0.3
Onondaga	21.4	Genesee	0.3
Oswego	5.3	Greene	0.3
Oneida	3.3	Herkimer	0.3
Orleans	2.6	Lewis	0.3
Broome	1.6	Livingston	0.3
Erie	1.6	Ontario	0.3
Madison	1.3	Schuyler	0.3
Niagara	1.0	Tioga	0.3
Allegany	0.7	Tompkins	0.3
Wayne	0.7	Ulster	0.3
Albany	0.3	Westchester	0.3
		No response	3.0

shore fishermen. Boat fishermen made 73,581 trips at an expenditure of some 1.3 million dollars. Shore fishing, which represented only 3.2 per cent of the weekend pressure and 9 per cent of the weekday pressure, contributed some $48,000 to the local economy. Estimated total "out-of-pocket costs" for the warmwater fishery in the study area during the census period were approximately 1.35 million dollars.

DISCUSSION

Results of this census demonstrate the importance and quality of the smallmouth bass fishery in eastern Lake Ontario. Approximately 52 per cent of the anglers surveyed actively sought this species. The estimated harvest was 183,324 bass with an additional 160,119 fish being caught and released. The average catch rate of 0.47 legal-sized bass per hour for the boat fishery was similar to those of 0.56 fish per hour in Canadian waters (Myers, 1977) and 0.55 fish per hour in Chaumont Bay (Jolliff and LeTendre, 1967). Differences in catch rates may reflect differences in size limits or annual variations in year-class strength. Canadian regulations did not impose a size limit, while in New York the minimum legal length was 12 inches at the time of the study. The difference between the catch rates in 1978 and 1966 in New York waters may reflect the increase in the size limit from 10 inches to 12 inches that became effective in 1978. The data suggest that there has been little change in the quality of the smallmouth bass fishery of eastern Lake Ontario during the 12-year period between surveys. The superiority of the bass fishery in the eastern basin is illustrated by comparing the catch rates there with those in other New York waters which averaged 0.10 bass per hour (creeled and released) and ranged from 0.003 to 0.43 during 1977 (Green, 1978).

Data collected during the creel census concerning the size of angler-caught bass were similar to catch records maintained by a group of trained angler cooperators. Of 766 bass caught by eight cooperators in the eastern basin, approximately 44 per cent, averaging 14 inches (356 millimeters) long, were creeled (Figure 4). They kept all fish over 12 inches long (the minimum legal size), suggesting that the release of 46.6 per cent of the bass reported caught during the census was largely in response to fishing regulations. Catch and release philosophies, such as "fishing for sport", were not an important factor in determining the harvest of smallmouth bass during the study in 1978.

Angler interest in yellow perch was second to that in smallmouth bass and, together with excellent angling success during open-water fishing as well as ice fishing (Franke, 1978), make it a valuable resource of eastern Lake Ontario.

Of some concern was the absence of northern pike in the sport catch during the census period. In 1966, northern pike was the third most commonly caught species in the eastern basin and second in angler preference

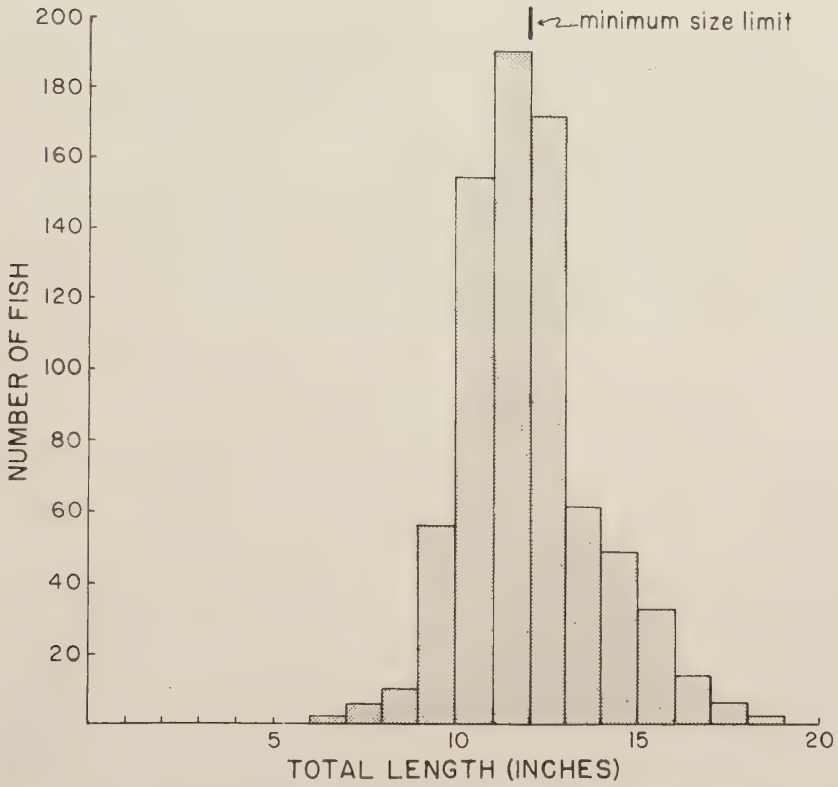

Figure 4. Length-frequency distribution of 766 angler-caught smallmouth bass in eastern Lake Ontario in 1978. All those more than 12 inches long were creeled.

Jolliff and LeTendre (1967). During the present survey, no anglers interviewed expressed an interest in pike. Although most pike fishing occurred during May and June (the season opened on the first Saturday in May), it was anticipated that such fishing would continue throughout the season. Myers (1978) reported northern pike as the third most commonly creeled species in Canadian waters of eastern Lake Ontario during the summer of 1977. Angler preference for northern pike in New York waters must therefore be very seasonal with interest shifting to other species as the season progresses. The high quality of the smallmouth bass fishery may greatly overshadow the pike fishery during the summer and fall. The importance of northern pike in providing winter angling opportunities in the eastern basin (Franke, 1978) and the St. Lawrence River (Pearce, 1961) has been demonstrated. Additional data would be needed to fully evaluate this fishery, particularly during May and June when the early-season pike fishing is at its best.

No attempt was made to further refine estimates of the economic value of the fishery. Fishing value, usually defined as the amount of money

anglers would be willing to pay for the privilege of fishing over and above that spent for normal fishing expenses, represents a dollar measure of the drawing power of a fishery and is not adequately measured by "out-of-pocket costs". Economic expansion factors have not been derived for Great Lakes fisheries and probably would not adequately describe local conditions. Development of economic demand curves for species by geographic area is the only acceptable method of projecting total value (Dwyer et al., 1977). Unfortunately, it is an extremely difficult method to apply because demand for each species must be evaluated in relation to where anglers live and the quality of the fishing available at specific locations. Such an analysis is beyond the scope of the data collected during this study.

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FOOD OF WHITE PERCH, ROCK BASS AND YELLOW PERCH IN EASTERN LAKE ONTARIO[1]

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ABSTRACT

The contents of stomachs from 1,485 white perch, 218 rock bass and 1,399 yellow perch collected in eastern Lake Ontario from May to October in 1972 and in May 1973 were examined. All three species fed primarily on amphipods, but they also ate chironomids and trichopterans regularly. Rock bass ate more trichopterans than chironomids, whereas white perch and yellow perch ate more chironomids. Snails and crayfish were significant items in the diet of rock bass, but occurred infrequently in stomachs of white perch and yellow perch. White perch and yellow perch frequently ate fish eggs during early summer, but rock bass seldom ate fish eggs. Fish were important in the diets of white perch longer than 300 millimeters and rock bass and yellow perch longer than 200 millimeters. Similarities in the diets of fish 1 year old or older suggest that the potential for competition between white perch and yellow perch is greater than that between rock bass and either white perch or yellow perch.

The fish community of Lake Ontario has changed greatly during the past 100 years, in both the relative abundance of species and species composition. Populations of a number of species that were principal components of this community in the late 1800's are now extinct or greatly reduced in these waters: lake sturgeon (*Acipenser fulvescens*), lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), lake herring (*C. artedii*), ciscoes (*Coregonus* spp.), burbot (*Lota lota*), walleye (*Stizostedion vitreum vitreum*), blue pike (*S. v. glaucum*) and fourhorn sculpin (*Myoxocephalus quadricornis*). The exotic alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*) and white perch (*Morone americana*) are now major components of this community. Recent salmonid management programs by both New York and the Province of

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Ontario have begun to establish sizable populations of brown trout (*Salmo trutta*), lake trout, rainbow trout (*Salmo gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*). Other important species are yellow perch (*Perca flavescens*), bullheads (*Ictalurus* sp.), sunfish (*Lepomis* sp.), rock bass (*Ambloplites rupestris*) and smallmouth bass (*Micropterus dolomieui*). Ecological relationships within the fish community that currently inhabits the lake are poorly understood.

During 1972, the United States and Canadian governments joined with private and public agencies in a broad program of physical, chemical and biological investigations on Lake Ontario under the auspices of the International Field Year on the Great Lakes. One objective of the survey on fishery resources was to collect comparative information on the diets of several species important in the sport fisheries; are these species feeding on different or the same organisms available to them? This paper describes and compares the seasonal stomach contents of 1,485 white perch, 218 rock bass and 1,399 yellow perch.

MATERIALS AND METHODS

White perch and yellow perch were collected with bottom trawls, gillnets, trap nets and seines during each month from May through October in 1972 at six locations in eastern Lake Ontario (Figure 1). Rock bass were collected with trawls and trap nets at two locations (Henderson Bay and Chaumont Bay). Additional specimens of white perch and rock bass were collected in May 1973. Nearly all gear was fished at depths of less than 10 meters. All young-of-the-year fish were preserved intact; older fish were either injected with 10 per cent formalin or the abdomen was slit before the fish was placed in formalin solution. At the laboratory, all specimens were measured (total length) and their digestive tracts were removed.

Students in an Ohio State University fish ecology class conducted at the F. T. Stone Laboratory at Put-in-Bay, Ohio, examined the stomach contents of yellow perch during the summer of 1974 and white perch during the summer of 1975. Food items were usually identified to class or order, with the aid of 10-30 × magnification. Each stomach was given from 0 to 10 points on the basis of fullness (0 if empty and 10 if full). The total points allotted to the stomach were then partitioned among the individual items according to their estimated contribution to the total stomach volume (Hynes, 1950). The points for all fish in each collection were combined by item, and the percentage that each item represented in the diet was calculated for the combined sample.

For rock bass, the digestive tracts (both the stomach and intestine) were examined at the Sandusky Biological Station of the U.S. Fish and Wildlife Service. Food items were identified with 10-30 × magnification, and the results were recorded as percentage frequency of occurrence in fish whose digestive tracts contained food.

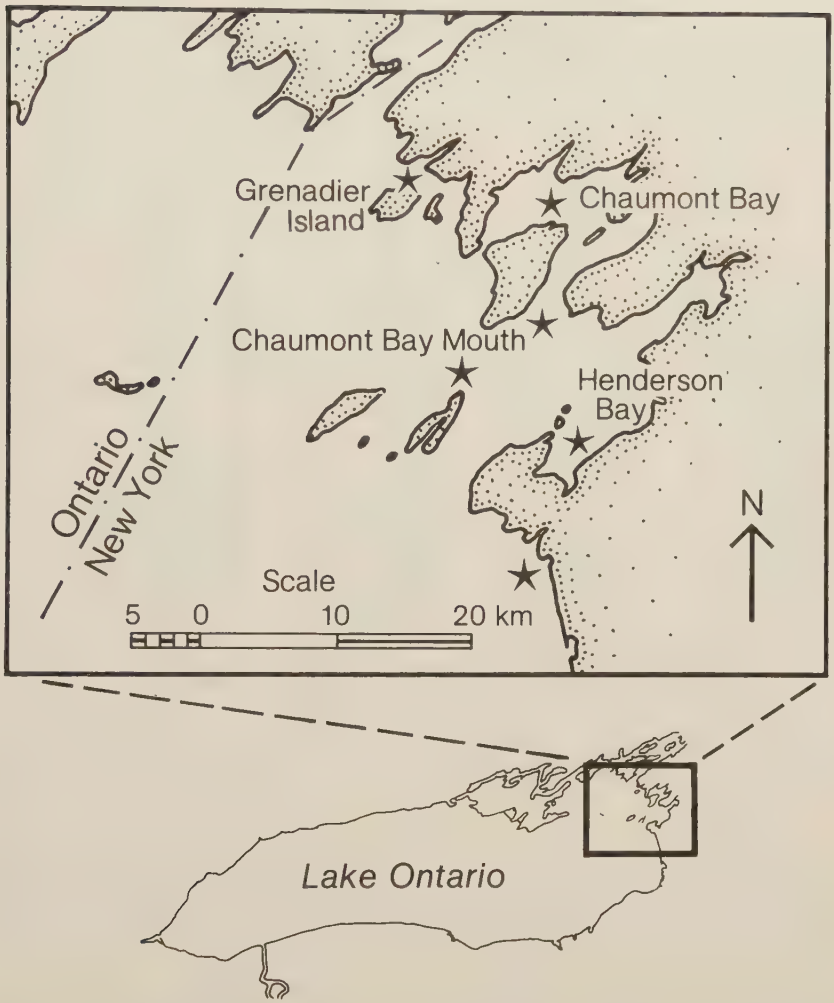

Figure 1. Locations (represented by stars) in eastern Lake Ontario where fish were collected for food study.

WHITE PERCH

Stomachs from all 600 young-of-the-year white perch examined contained food. Copepods, cladocerans and amphipods were the major items (Table 1.) Cladocerans were more important during the summer than in the fall, and amphipods became more important in the diet in the fall. The shift from cladocerans to amphipods may have been due to the increasing size of these young fish.

Stomach contents of 98 of the young-of-the-year white perch collected near Gernadier Island in September were examined in relation to fish

Table 1. Food of Young-of-the-year White Perch Collected in Eastern Lake Ontario in 1972, Expressed As Mean Percentage of Total Volume of Stomach Contents

Date of collection	Number of fish	Mean total length*	Food items§					
			Copepoda	Cladocera	Amphipoda	Chironomidae	Other†	Unidentified
Summer								
August 21-28	33	25	19	35	t	25	8	13
August 30-September 6	96	41	36	33	4	5	7	15
Fall								
September 11-14	195	49	26	9	40	4	3	18
September 20-21	133	54	42	4	27	4	12	11
October 4-13	59	64	28	38	22	7	3	2
October 17	84	53	30	18	34	8	0	10

*In millimeters.
§t = less than 0.5 per cent.
†Diptera, fish, Corixidae, Nematoda, Bryozoa, filamentous algae, Ostracoda, Rotifera, Isopoda, Trematoda, Trichoptera and Porifera.

Table 2. Food of Young-of-the-year White Perch Collected Near Grenadier Island in Lake Ontario on September 20, 1972, According to Length, Expressed As Mean Percentage of Total Volume of Stomach Contents

Length*	Number of fish	Food item §						
		Copepoda	Amphipoda	Ostracoda	Chironomidae	Cladocera	Other†	Unidentified
26-35	14	84	2	t	1	2	1	10
36-45	13	78	10	2	2	1	t	6
46-55	12	50	6	19	5	3	10	8
56-65	32	25	42	6	8	2	7	10
66-75	23	24	38	8	3	3	4	20
76-85	4	2	44	13	2	0	18	21

*In millimeters.
§t = less than 0.5 per cent.
†Diptera, Corixidae, Nematoda, Bryozoa, filamentous algae, Rotifera, Isopoda, Trematoda, Trichoptera and Porifera.

length. Copepods made up 50 per cent or more of the food volume of specimens 26 to 55 millimeters long but decreased in importance as the length of the fish increased (Table 2). Amphipods were the principal food of fish longer than 55 millimeters. Ostracods, chironomids and cladocerans consistently occurred in the stomachs in small volumes.

Stomach contents of young-of-the-year white perch collected September 13-21 at four locations (Figure 2) indicated differences in diet among fish from the different areas. Amphipods were the major food items at the mouth of Chaumont Bay and in Henderson Bay, and copepods predom-

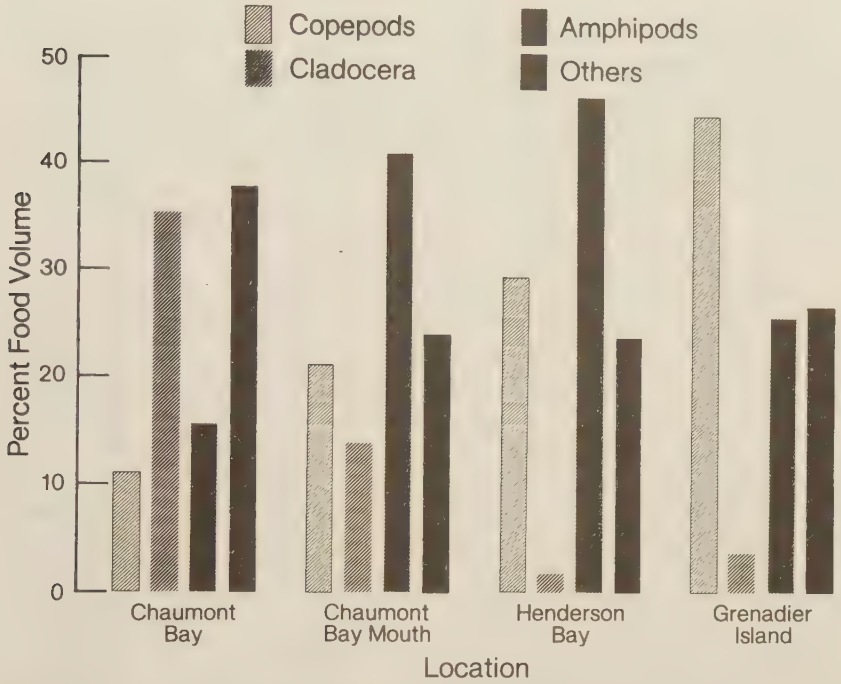

Figure 2. Food of young-of-the-year white perch collected at four locations in eastern Lake Ontario, September 13-21, 1972, expressed as a percentage of total volume of stomach contents. Mean lengths of these perch ranged from 49 to 54 millimeters at the four areas.

inated at Grenadier Island. Cladocerans, a significant food in Chaumont Bay, made up only a small part of the food volume in the other areas. Differences in diet were probably due to differences in the availability of items in the different areas rather than to selectivity by the young white perch.

For yearling and older white perch, amphipods were the predominant food, making up 24 per cent or more of the volume for specimens of all size groups from May through October (Table 3). Chironomids were an important food of white perch less than 200 millimeters long, especialy in the spring, but they made up successively smaller proportions of the volume in the summer and fall. Trichopterans were a significant part of the diet only among fish less than 150 millimeters long and primarily in the spring. Fish eggs made up about one-fourth of the food of specimens 150 to 299 millimeters long during May and June. The consumption of fish eggs was considerably lower in the summer and fall than in the spring, most likely because availability decreased. Fish were seldom eaten by white perch less than 200 millimeters long but were an important item in the diet of larger individuals. The increased use of fish in the fall was probably a result of greater availability of young of the year as forage.

Table 3. Food of Yearling and Older White Perch Collected at Six Locations in Eastern Lake Ontario During October in 1972, According to Length and Season, Expressed As Mean Percentage of Total Volume of Stomach Contents

Length*	Number of fish	Food item§						
		Amphipoda	Chironomidae	Trichoptera	Fish eggs	Fish	Other†	Unidentified
Spring (May and June)								
50- 99	4	44	40	1	0	t	14	0
100-149	14	24	40	30	0	t	5	0
150-199	64	20	13	11	20	t	12	4
200-249	108	44	10	4	24	2	9	7
250-299	61	33	4	2	29	18	13	2
300 +	11	38	4	0	3	53	2	t
Summer (July and August)								
59- 99	8	42	28	7	0	0	22	1
100-149	36	35	32	10	0	0	18	5
150-199	89	45	20	6	7	5	12	6
200-249	40	37	6	6	14	4	22	6
250-299	13	38	3	4	8	29	15	11
300 +	0	. .	. .	. .	. .	. .	. .	. .
Fall (September and October)								
59- 99	0	. .	. .	. .	. .	. .	. .	. .
100-149	18	45	14	2	t	0	36	2
150-199	130	60	10	1	1	8	16	3
200-249	132	47	9	3	1	28	7	6
250-299	26	26	4	1	t	56	8	5
300 +	4	26	1	0	1	64	1	7

*In millimeters.

§t = less than 0.5 per cent.

†Isopoda, Diptera, Cladocera, filamentous algae, Ostracoda, Gastropoda, Pelecypoda, Copepoda, Decapoda, plant material, Nematoda, Bryozoa, Hirudinea, Plecoptera, Simuliidae, Coleoptera, unidentified insects, Arachnidae, Porifera, Rotifera, Odonata and Trematoda.

ROCK BASS

Major items in the diet of rock bass were amphipods (*Gammarus* and *Hyalella*), trichopterans, gastropods (*Valvata, Gyraulus* and *Bithinia*), decapods, chironomids and fish (Table 4). The fish were mainly alewives, followed by rainbow smelt, trout-perch (*Percopsis omiscomaycus*) and yellow perch. Too few digestive tracts were examined to determine

TABLE 4. FOOD OF ROCK BASS COLLECTED IN HENDERSON BAY AND CHAUMONT BAY IN EASTERN LAKE ONTARIO DURING 1972-1973, EXPRESSED AS PERCENTAGE FREQUENCY OF OCCURRENCE IN STOMACHS CONTAINING FOOD

Food item	May	June	July	August	September	October
Amphipoda	38	88	63	81	100	25
Trichoptera	18	25	84	45	0	0
Gastropoda	2	75	32	47	33	0
Decapoda	46	50	10	14	0	25
Fish	30	0	5	3	0	75
Chironomidae	2	25	10	17	0	0
Isopoda	5	12	5	2	0	0
Hirudinea	3	0	0	5	0	0
Pelecypoda	2	12	0	0	0	0
Coleoptera	2	0	5	3	33	0
Unidentified insects	2	12	10	5	0	0
Fish eggs	0	0	5	0	0	0
Orthoptera	0	0	0	3	0	0
Lepidoptera	0	0	0	2	0	0
Hymenoptera	0	0	0	2	0	0
Araneae	0	0	0	2	0	0
Number of stomachs	96	8	20	86	4	4
Number with food	61	8	19	58	3	4
Mean length (millimeters)	210	180	150	169	110	127

TABLE 5. FOOD OF ROCK BASS COLLECTED IN HENDERSON BAY AND CHAUMONT BAY IN EASTERN LAKE ONTARIO DURING 1972-1973, ACCORDING TO LENGTH, EXPRESSED AS PERCENTAGE FREQUENCY OF OCCURRENCE IN STOMACHS CONTAINING FOOD

	Length (millimeters)		
Food item	Under 150	150-200	Over 200
Amphipoda	81	75	29
Trichoptera	50	44	17
Gastropoda	19	46	4
Decapoda	9	24	46
Fish	3	6	38
Chironomidae	6	14	6
Isopoda	3	6	2
Hirudinea	0	7	0
Pelecypoda	0	1	2
Coleoptera	3	4	2
Unidentified insects	3	7	2
Fish Eggs	0	1	0
Orthoptera	3	0	2
Lepidoptera	3	0	0
Hymenoptera	0	1	0
Araneae	0	1	0
Number of stomachs	34	104	78
Number with food	32	71	48

whether differences existed in the diets of fish from Henderson Bay and Chaumont Bay.

Enough fish were collected to examine seasonal trends in diet only during May and August. Although a greater variety of organisms was consumed during August, the most striking differences were in the high occurrence of fish and the low incidence of gastropods during May in comparison with August (Table 4). Amphipods and trichopterans were also eaten more frequently during August. However, the greater mean length of the fish in the May sample, rather than a seasonal trend in diet, may have been responsible for these differences.

As the mean length of rock bass increased, amphipods and trichopterans occurred less frequently in the diet, whereas decapods (crayfish) and fish were eaten more often (Table 5). Gastropods (snails) and chironomids occurred most frequently in the digestive tracts of rock bass 150 to 200 millimeters long.

YELLOW PERCH

Amphipods were the predominant food of yellow perch in eastern Lake Ontario, making up 24 to 69 per cent of the food volume each month (Table 6). Chironomids and fish were both staples and usually ranked second or third highest in food volume. Fish eggs were an important part of the diet during early summer and made up 25 per cent of the food volume during July. Eggs of several species were available to yellow perch during this time, although most were probably those of the alewife. Trichopterans and isopods were consistently eaten in small amounts each month. Other food items appeared irregularly and in small amounts.

Amphipods were the predominant item, followed by chironomids, in stomachs of yellow perch less than 200 millimeters long (Table 7). Fish became increasingly important in the diet as the mean length of the perch

Table 6. Food of Yellow Perch Collected in Eastern Lake Ontario During 1972, Expressed As Mean Percentage of Total Volume of Stomach Contents*

Food item	May	June	July	August	September	October
Amphipoda	69	34	24	57	48	44
Isopoda	1	1	1	3	1	1
Chironomidae	6	7	20	18	18	20
Trichoptera	1	6	4	2	t	10
Fish eggs	4	8	25	t	t	0
Fish	5	26	12	10	30	13
Other§	1	10	7	5	5	3
Unidentified	13	8	8	5	3	9
Number of stomachs	65	298	329	382	190	135
Length (millimeters)						
Mean	170	193	170	178	177	175
Range	100-271	62-290	82-292	121-255	121-255	92-270

*t = less than 0.5 per cent.

§Nematoda, Bryozoa, Annelida, Cladocera, Copepoda, Ostracoda, Decapoda, Hydracarina, Ephemeroptera, Hemiptera, Coleoptera, Diptera, Gastropoda, Pelecypoda, algae, rooted aquatic vegetation and seeds.

TABLE 7. FOOD OF YELLOW PERCH COLLECTED IN EASTERN LAKE ONTARIO FROM JUNE TO OCTOBER IN 1972, ACCORDING TO LENGTH, EXPRESSED AS MEAN PERCENTAGE OF TOTAL VOLUME OF STOMACH CONTENTS*

Food item	Length (millimeters)		
	Under 150	150-200	Over 200
Amphipoda	46	42	23
Isopoda	2	t	1
Chironomidae	29	22	8
Trichoptera	0	1	2
Fish eggs	9	9	2
Fish	7	16	43
Other§	5	6	10
Unidentified	2	4	11
Number of stomachs	134	249	196

*t = less than 0.5 per cent.
§Nematoda, Bryozoa, Annelida, Cladocera, Copepoda, Ostrcoda, Decapoda, Hydracarina, Ephemeroptera, Hemiptera, Coleopera, Diptera, Gastropoda, Pelecypoda, algae, rooted aquatic vegetation and seeds.

increased and was the principal food of those longer than 200 millimeters. Yellow perch of all sizes ate fish eggs, although such eggs were a minor part of the food volume in specimens over 200 millimeters long. Indices of stomach fullness, as computed by the points method, were similar for all size groups. Although yellow perch 150 to 200 millimeters long generally consumed a greater variety of food items than did either shorter or longer fish, neither isopods, trichopterans nor any of the 17 other food items were a substantial part of the diet.

Although fish remains in yellow perch stomachs were generally not identifiable, alewives, rainbow smelt, bass (*Morone* sp.), sunfish, darters (*Etheostoma* sp.) and sculpins (*Cottus* sp.) were recognized. No single species or genus was predominant. The relative volume of fish in the diet was greatest in June and September (Table 6). The larger volume of fish eaten in June probably reflected the larger size of yellow perch in the sample collected that month, whereas that in September probably resulted from greater availability of small young-of-the-year fish in nearshore waters.

COMPARISONS BETWEEN SPECIES

The principal food of white perch, rock bass and yellow perch in the nearshore waters of eastern Lake Ontario was amphipods. Heavy use of amphipods was probably due to their availability, since they are one of the most abundant benthic organisms (Hiltunen, 1969; Casey et al., 1973). Amphipods in white perch and yellow perch stomachs were not identified to genus, but only *Gammarus* and *Hyalella* were present in rock bass stomachs.

Chironomids and trichopterans were eaten regularly by all three species, although rock bass ate more trichopterans than chironomids, and white perch and yellow perch ate more chironomids. Snails and crayfish were

significant items in the diet of rock bass, but they occurred infrequently in white perch or yellow perch stomachs. Fish eggs, an important item for white perch and yellow perch, were seldom eaten by rock bass.

Other studies have shown that white perch, rock bass and yellow perch eat a great variety of organisms, and that the predominant food items vary among populations and are probably largely dependent on availability of the organisms. For example, insects predominated in the diet of yellow perch in 24 Wisconsin lakes, although there was considerable variation among the lakes and from year to year in the same lake (Couey, 1935). In Lake Opinicon in Ontario, isopods were the primary food (Keast and Welsh, 1968). Yellow perch evidently eat fish eggs whenever opportunity arises (Hoffman, 1918; Wolfert et al., 1975). Leach (1962) reported that white perch from the Bay of Quinte had a diverse diet that varied with the length of the fish and the time of year and that dipterans were the most important food of those less than about 200 millimeters long, while longer perch ate mostly fish. The diet of rock bass, like that of yellow perch, in 24 Wisconsin lakes varied from lake to lake and within a given lake (Couey, 1935), and variation in diet was associated with the season and depth of capture as well as the size of the fish.

White perch, yellow perch and, to some extent, rock bass appear to be consuming the same foods in the nearshore community of eastern Lake Ontario, and individuals of all three species were frequently captured in the same nets. The eastern outlet basin and smaller embayments (e.g., Chaumont Bay and Henderson Bay) where these species are especially abundant are eutrophic, and biological production at all trophic levels is relatively high. Growth rates of white perch, yellow perch and rock bass are good compared with those of populations in other waters. Competition for the same food, in the classical sense of being so intense as to result in growth depression of one or more species, does not seem to exist. Nevertheless, the similarity of diets suggestss that, among fish 1 year old or older, the potential for competition is greater between white perch and yellow perch than between rock bass and either white perch or yellow perch.

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COMPARISON OF FARMERS' ATTITUDES TOWARD DEER ABUNDANCE IN TWO REGIONS OF NEW YORK HAVING DIFFERENT AGRICULTURAL AND DEER POPULATION CHARACTERISTICS[1]

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ABSTRACT

Questionnaire surveys to assess the attitudes of farmers toward deer and deer abundance and their preferences with respect to future trends in the deer population level were conducted in the Lake Plain (a fruit growing area) and Central Plain (a dairy farming area) regions of New York. The majority of respondents considered deer to be aesthetically valuable. As the deer population increased, the proportion concerned about crop damage increased, to a greater degree in the Lake Plain than in the Central Plain. Although farmers in both regions exhibited considerable tolerance for deer at most population densities, the data demonstrated the differences that can exist and that must be considered in formulating deer management strategies.

Surveys to assess the attitudes of farmers toward deer and deer abundance and their preferences with respect to future trends in the deer population level have been conducted in central and western New York by the Department of Natural Resources at Cornell University in cooperation with the State Department of Environmental Conservation (Brown et al., 1977, 1978b, 1979). Using data for the Lake Plain, Brown et al. (1978a) evaluated farmers' tolerance of economic loss caused by deer damage of crops, and Brown and Decker (1979) suggested a means for considering farmers' attitudes in determining an optimum deer population density for the area. The present paper compares the attitudes of farmers in this region toward deer abundance with those of farmers in the Central Plain.

The extent of each region as used in this study is shown in Figure 1. Their agricultural characteristics differ: the Lake Plain (86 towns) is a highly productive fruit growing area, while the Central Plain (111 towns) is predominantly a dairy farming area (Brown et al., 1980). They differ also in the history of their deer populations, that in the Lake Plain having been managed at a considerably lower level to lessen damage to orchards and other cash-crop farms.

The study constituted a questionnaire survey of farmers as described by Brown et al. (1980). A total of 12,255 questionnaires were mailed, of

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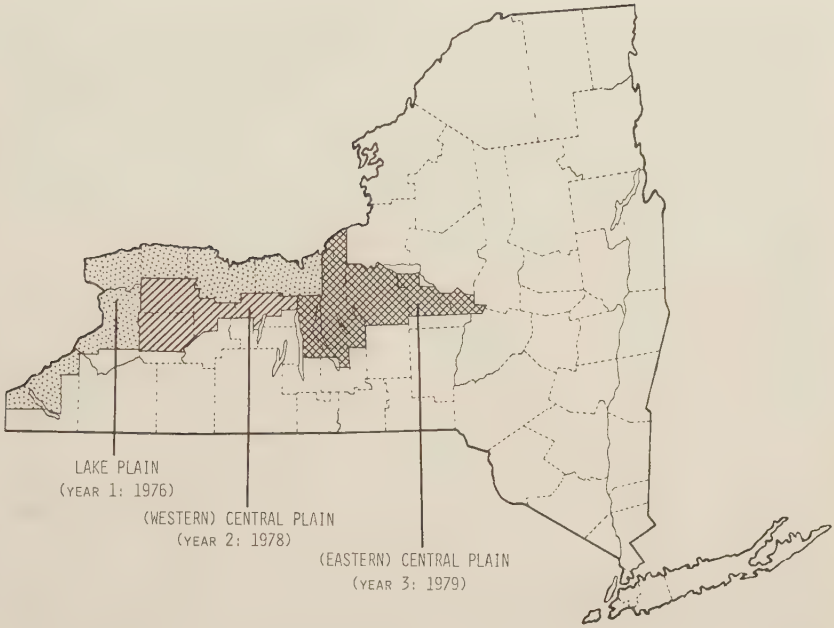

Figure 1. Map of New York State showing location of the regions used in comparing farmers' attitudes toward deer abundance.

which 233 were not deliverable and 9,543 (79.4 per cent) were returned and useable. However, only responses from farmers who derived over 75 per cent of their household income from farming (1,040 in the Lake Plain and 1,861 in the Central Plain) are used in this paper. Only "full time" farmers are considered because they are the ones likely to be affected most significantly by crop damage caused by deer and because they have been found to have the most conservative attitudes toward the presence of deer (Brown et al., 1977, 1978a, 1978b, 1979).

Respondents were grouped according to the average number of legal-sized (i.e., having antlers 3 inches or more long) adult bucks taken by hunting per square mile of deer habitat during the preceding three years in the town in which they lived.[2] In the Central Plain, five levels of deer population density in terms of this index were recognized: 1.00 and less, 1.01 to 2.00, 2.01 to 3.00, 3.01 to 4.00, and over 4.00 bucks taken per square mile. In the Lake Plain, because few towns had high densities, only four levels were recognized: 1.00 and less, 1.01 to 2.00, 2.01 to 3.00, and over 3.00.

For all levels of deer population density in both regions, the majority of

[2]The number of bucks taken per square mile of deer habitat may be converted to an approximation of the actual deer population per square mile by multiplying it by 6.39 (Severinghaus, 1965).

the respondents unconditionally considered deer to be aesthetically valuable (Table 1). However, as the density increased, this proportion decreased and that of respondents who said they liked deer but worried about deer damage to their crops increased. At the highest deer popula-

Table 1. Attitudes of Responding Farmers in Lake Plain and Central Plain Toward Presence of Deer, According to Density of Deer Population

Deer population density*	Number of respondents	Attitude toward deer§			
		Aesthetically valuable	Worry about crop damage	Nuisance	Indefinite
Lake Plain					
0.01-1.00	599	72.6 (435)	14.4 (86)	3.3 (20)	9.7 (58)
1.01-2.00	297	71.4 (212)	16.8 (50)	3.4 (10)	8.4 (25)
2.01-3.00	99	59.6 (59)	22.2 (22)	6.1 (6)	12.1 (12)
3.01 & over	40	50.0 (20)	32.5 (13)	12.5 (5)	5.0 (2)
Total	1,035	70.1 (726)	16.5 (171)	4.0 (41)	9.4 (97)
Central Plain					
0.01-1.00	207	74.4 (154)	14.0 (29)	2.4 (5)	9.2 (19)
1.01-2.00	850	75.0 (637)	12.9 (110)	2.0 (17)	10.1 (86)
2.01-3.00	452	73.1 (331)	17.3 (78)	2.7 (12)	6.9 (31)
3.01-4.00	216	68.5 (148)	19.4 (42)	2.8 (6)	9.3 (20)
4.01 & over	130	60.8 (79)	20.0 (26)	6.9 (9)	12.3 (16)
Total	1,855	72.7 (1,349)	15.4 (285)	2.6 (49)	9.3 (172)

*As adult bucks taken by hunting per square mile of deer habitat (3-year average).
§As percentage of respondents; figures in parentheses represent number of respondents.

tion density in the Lake Plain about a third of the respondents worried about crop damage, whereas at the highest densities (3.01 to 4.00 and over 4.00) in the Central Plain only about a fifth were concerned.

In both regions, the proportion of respondents reporting no deer damage decreased as the deer population increased (Table 2). However, in the Lake Plain 22 per cent of those in towns where the buck take exceeded 3.00 per square mile described their damage as "substantial" or "severe". This was three times the proportion in the Central Plain for towns where the buck take was 3.01 to 4.00 per square mile and twice that where the take exceeded 4.00 per square mile.

As deer abundance increased, farmers' feelings about their damage shifted from "not aware of any damage" or "negligible" to "tolerable" or "unreasonable" (Table 3). In the Lake Plain, in towns where the buck take exceeded 3.00 per square mile, 10 per cent of the respondents were not aware of any damage and 30 per cent considered their damage unreasonable. In the Central Plain, however, at the same or higher deer population levels, 23 to 35 per cent were not aware of damage and only 8 to 13 per cent considered their damage unreasonable.

Farmers' preferences with respect to future trends in deer abundance (Figure 2) reflect the differences between the two regions in their tolerance of deer population densities. In the Lake Plain, tolerance of greater deer abundance was substantially lower among respondents in towns where the

TABLE 2. RESPONDING FARMERS' ASSESSMENT OF DEGREE OF DEER DAMAGE IN LAKE PLAIN AND CENTRAL PLAIN, ACCORDING TO DENSITY OF DEER POPULATION

Deer population density*	Number of respondents	Degree of damage§				
		None	Light	Moderate	Substantial	Severe
Lake Plain						
0.01-1.00	603	57.0 (344)	36.0 (217)	5.5 (33)	1.3 (8)	0.2 (1)
1.01-2.00	298	48.7 (145)	43.6 (130)	5.7 (17)	1.7 (5)	0.3 (1)
2.01-3.00	98	52.1 (51)	27.6 (27)	11.2 (11)	7.1 (7)	2.0 (2)
3.01 & over	41	24.4 (10)	39.0 (16)	14.6 (6)	9.8 (4)	12.2 (5)
Total	1,040	52.9 (550)	37.5 (390)	6.4 (67)	2.3 (24)	0.9 (9)
Central Plain						
0.01-1.00	206	55.7 (115)	33.5 (69)	7.8 (16)	1.5 (3)	1.5 (3)
1.01-2.00	855	50.9 (435)	39.2 (335)	7.1 (61)	2.2 (19)	0.6 (5)
2.01-3.00	453	43.2 (196)	38.9 (176)	13.7 (62)	3.3 (15)	0.9 (4)
3.01-4.00	217	38.3 (83)	41.4 (90)	13.4 (29)	5.1 (11)	1.8 (4)
4.01 & over	130	30.0 (39)	51.5 (67)	8.5 (11)	9.2 (12)	0.8 (1)
Total	1,861	46.7 (868)	39.6 (737)	9.6 (179)	3.2 (60)	0.9 (17)

*As adult bucks taken by hunting per square mile of deer habitat (3-year average).
§As percentage of respondents; figures in parentheses represent number of respondents.

TABLE 3. RESPONDING FARMERS' ASSESSMENT OF IMPORTANCE OF DEER DAMAGE IN LAKE PLAIN AND CENTRAL PLAIN, ACCORDING TO DENSITY OF DEER POPULATION

Deer population density*	Number of respondents	Importance of damage§			
		Not aware of damage	Negligible	Tolerable	Unreasonable
Lake Plain					
0.01-1.00	596	23.7 (141)	50.1 (299)	23.0 (137)	3.2 (19)
1.01-2.00	299	15.7 (47)	53.8 (161)	27.8 (83)	2.7 (8)
2.01-3.00	96	14.6 (14)	39.6 (38)	38.5 (37)	7.3 (7)
3.01 & over	40	10.0 (4)	32.5 (13)	27.5 (11)	30.0 (12)
Total	1,031	20.0 (206)	49.6 (511)	26.0 (268)	4.4 (46)
Central Plain					
0.01-1.00	206	49.0 (101)	27.7 (57)	20.4 (42)	2.9 (6)
1.01-2.00	832	44.5 (371)	26.6 (221)	25.5 (212)	3.4 (28)
2.01-3.00	442	36.0 (159)	30.3 (134)	28.5 (126)	5.2 (23)
3.01-4.00	208	34.6 (72)	22.6 (47)	34.6 (72)	8.2 (17)
4.01 & over	128	23.4 (30)	34.4 (44)	28.9 (37)	13.3 (17)
Total	1,816	40.4 (733)	27.7 (503)	26.9 (489)	5.0 (91)

*As adult bucks taken by hunting per square mile of deer habitat (3-year average).
§As percentage of respondents; figures in parentheses represent number of respondents.

buck take was more than 3.00 per square mile than where it was less, and even where it was 2.01 to 3.00 per square mile about a quarter preferred to have the deer population decrease. In the Central Plain also, as deer abundance increased so did the proportion of respondents who wanted a decrease in the population. However, the difference was much less dramatic and even where the buck take exceeded 4.00 per square mile a majority wanted the population to remain the same.

Assuming that an expression of preference for a "decrease" indicated that the existing deer population was unacceptable, these data reveal that in the Lake Plain this view was held by a majority of the respondents where

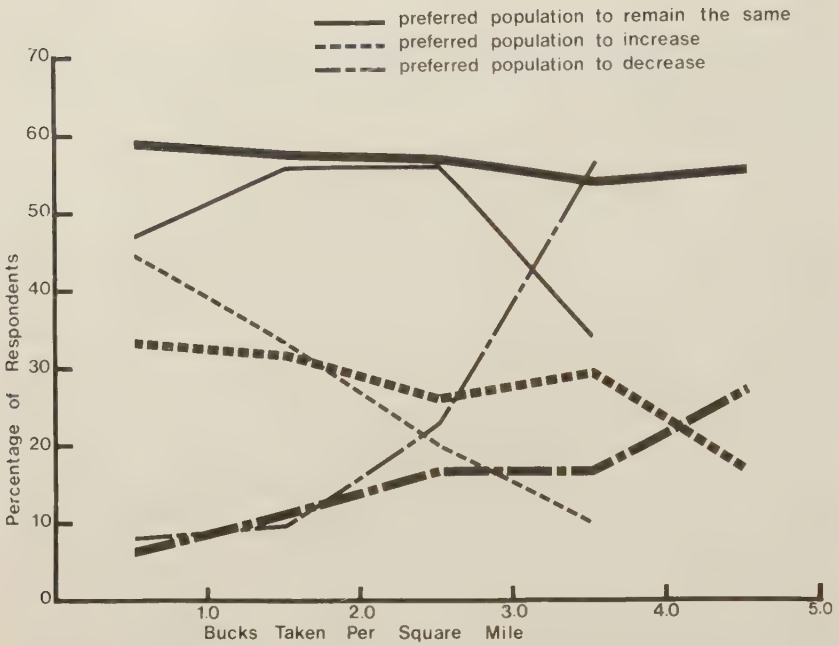

Figure 2. Relative proportion of respondents who expressed preference for future deer population levels to remain the same, increase or decrease in the Lake Plain (light lines) and Central Plain (heavy lines), according to different population densities in terms of bucks taken per square mile.

the buck take exceeded 3.00 per square mile. In the Central Plain, on the other hand, at no density for which a substantial sample was obtained did the respondents consider the population level unacceptable.

An analysis of farmers' preferences in each county or town within a region almost certainly would have given different results in many cases than those for the region as a whole, but there are practical limits to the level of specificity in a questionnaire and to the minimum size of an area for effective deer management. Good examples of reasonable deer management units are those (some 100 to 1,200 square miles in size) recognized by the State Department of Environmental Conservation. Regions such as those discussed in this paper, each having similar physiographic, agricultural and deer population characteristics, probably constitute the broadest type of area that should be designated if farmers' preferences are to be equitably considered.

Farmers in both regions exhibited considerable tolerance for deer at most population densities that occurred in their respective regions. The pervasiveness of this positive attitude is encouraging for deer management. However, the data on farmers' attitudes toward deer and deer damage and their preferences for future trends in deer abundance demonstrate the differences in acceptable deer population densities that can exist between ad-

jacent regions having dissimilar agricultural characteristics and deer management histories. Such differences must be recognized and considered in formulating management strategies for altering deer population levels in areas of this sort. Nevertheless, the potential exists to achieve greater farmer tolerance of larger deer populations in agricultural areas such as New York's Lake Plain if special attention is given to alleviating severe deer damage problems.

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LIMING ACID PONDS IN NEW YORK

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ABSTRACT

The use of lime to neutralize acid conditions in ponds has been an accepted management tool in New York for some 20 years. This paper reviews various treatments, considering changes in pH, alkalinity and fish populations, and presents data on cost-benefit ratios. It is concluded that, for both accessible and remote ponds, liming is effective and economically feasible.

Acid precipitation has been much in the news in recent years. Cause and effects have been described by Schofield (1976b) and others. In New York, the effects are most serious in ponds at higher elevations in the Adirondack region, which historically are poorly buffered. Typically, pristine ponds have a pH of 6.5 or less and an alkalinity of 50 μeq/l or less. Brook trout, indigenous to Adirondack ponds, are somewhat tolerant of acid conditions, but reproductive success is limited when the pH drops below 5.0-5.5 and alkalinity below 5 μeq/l (Schofield, 1976a). As acid conditions worsen, brook trout and associated species no longer survive.

Of 2,109 Adirondack ponds (open to the public) totalling 183,000 acres (Pfeiffer, 1979), 170 (7,375 acres) are known casualties of acid precipitation with the number increasing each year.[1] Although public awareness and concern over the situation is keen, excellent fishing in hundreds of ponds is still available. Acid precipitation and subsequent loss of additional fishing opportunity will constitute a problem for future fisheries management in this region.

Pond liming is not new; fisheries workers in New York have been liming ponds since the late 1950's. While some experiments were conducted with different forms of lime, hydrated lime ($Ca[OH]_2$) was used almost exclusively. Plosila (1966) studied the effects of various application rates on water chemistry and fish survival in 19 ponds in the late 1950's and early 1960's. He adopted rates of 10 to 25 pounds of hydrated lime per acre foot depending on the severity of acid conditions and the type of pond. Bog ponds received the higher rate; clear ponds, the lower.

Selecting candidate ponds for treatment is straight forward. In addition to having an acid condition, a pond must meet the following criteria:

1. have a flushing rate of more than one year
2. be suitable habitat for trout survival and growth
3. be open to public fishing

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[1]Statements in the present tense concerning the status of ponds and the treatment program in New York reflect the situation in 1979.

Priority is given to ponds accessible by road and to ponds with a history or potential for natural reproduction of trout. Threatened ponds containing a heritage strain of brook trout receive the highest priority.

Application of hydrated lime is restricted to open-water periods. If spread on ice, it "reverts" to the less potent $CaCO_3$. Since it costs twice as much as agricultural lime ($CaCO_3$), loss of its greater neutralizing capacity makes it economically expedient to use it in its most active form. The advantage of hydrated lime is its superior buffering capacity. On a weight basis, compared with agricultural lime, approximately one-fifth as much is needed to treat a pond. For example, a 20-acre pond with an average depth of 20 feet would be treated with 2 to 5 tons of hydrated lime in contrast with 10 to 20 tons of agricultural lime. On the negative side, hydrated lime dissolves instantly and its effects are generally short-lived and depend on the flush rate of the pond. Also, pH shock has been reported to be potentially harmful to certain aquatic fauna (Schneider et al., 1975).

To date, 50 ponds have been treated with hydrated lime, some more than once. Follow-up studies to evaluate results were not always as complete as might be desired. Nevertheless, 35 treatments resulted in measurable improvements in water quality and fish survival. Many of these ponds were completely barren of fish life prior to treatment, but after treatment they produced excellent fishing (Blake, 1977).

In recent years, a shift to the use of agricultural lime has taken place, primarily in an effort to extend the time between treatments. Commercially available limestone is a mixture of particle sizes. The very fine particles produce an immediate, but less sharp, increase in pH, while progressively larger particles dissolve more slowly. There has been too little time to thoroughly evaluate the use of agricultural lime. However, private ponds treated with it have proven to retain the effect longer than in the case of hydrated lime (Dwight Webster, personal communication). Agricultural lime is applied at a rate of ½ to 1 ton per surface acre. A more precise application rate based on water chemistry is being developed. For the present, 1 ton per acre is the rule for initial treatments.

In accessible ponds application is the same for both types of lime; the lime is dumped from bags from a slowly moving boat. More lime is spread in shallow-water areas (i.e., 3 to 20 feet) than over deep-water areas. The purpose here is to place the lime where the fish live and to expose it to wave action and currents as much as possible. Six ponds totalling 90 acres have been treated in this manner (Table 1).

Moving large quantities of lime to remote areas is more complicated. To date, Department efforts have been limited to the use of a helicopter. However, fixed-wing aircraft have been used successfully elsewhere (Dwight Webster, personal communication). Four means of transporting lime by helicopter have been tested. Three proved impractical for a number of reasons, high labor costs being the principal factor.

TABLE 1. SUMMARY OF DATA CONCERNING PONDS LIMED IN NEW YORK BY THE STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, 1975-1979

Name	County	Watershed	Pond No.*	Acres	Liming treatment					Justification
					Date	Type	Amount	Delivery	Cost (dollars)	
Clear Lake	Herkimer	Oswegatchie-Black	625	204	March 1975	Hydrated	18 tons	Helicopter§	2,700	History of high use
					February 1977	Hydrated	36 tons	Helicopter§	2,340	
Tomkettle Lake	Oneida	Mohawk-Hudson	809	12	September 1975	Hydrated	0.9 ton	Boat	125	History of high use
Townline Pond	St. Lawrence	St. Lawrence	371	36	October 1975	Hydrated	6.5 tons	Boat	682	History of high use
Pine Pond	St. Lawrence	St. Lawrence	368	16	October 1975	Hydrated	1.5 tons	Boat	245	History of high use
					November 1977	Agricultural	8 tons	Boat	462	
Long Pond	Lewis	Oswegatchie-Black	610	20	October 1975	Hydrated	1.25 tons	Boat	165	History of high use
Pitcher Pond	Lewis	Oswegatchie-Black	662a	5	October 1975	Hydrated	0.75 ton	Boat	95	History of high use
Payne Lake	Lewis	Oswegatchie-Black	620	18	October 1975	Hydrated	2 tons	Boat	195	History of high use
Evies Pond	Lewis	Oswegatchie-Black	608	5	October 1975	Hydrated	0.75 ton	Boat	98	History of high use
Horn Lake	Herkimer	Oswegatchie-Black	845	38	November 1975	Hydrated	4.5 tons	Helicopter†	2,370	Preserve heritage strain of brook trout
					October 1978	Agricultural	20 tons	Helicopter	3,786	
Falls Pond	Hamilton	Oswegatchie-Black	885	40	November 1975	Hydrated	5 tons	Helicopter†	2,495	History of high use
					October 1978	Agricultural	20 tons	Helicopter	5,242	
Duell Pond	Franklin	Lake Champlain	195	1.5	August 1976	Hydrated	900 pounds	Boat	120‡‡	High use; popular roadside brook trout pond
Florence Pond	Lewis	Oswegatchie-Black	664a	3.5	September 1976	Agricultural	3.5 tons	Boat	285	High use; one of few brook trout ponds in area
Cooler Pond	Franklin	St. Lawrence	205	1	September 1976	Hydrated	300 pounds	Boat	40‡‡	High use; roadside pond on Paul Smith's College campus
Duck (Echo) Pond	Franklin	Lake Champlain	136	10	September 1976	Hydrated	3.25 tons	Boat	450‡‡	High use; on Fish Creek Ponds campsite
Nine Corner Lake	Fulton	Mohawk-Hudson	719	110	May 1977	Hydrated	21.25 tons	Boat	7,743	History of high use; preserve fishery in one of few brook trout ponds in county
					November 1979‡	Hydrated	21 tons	Helicopter	15,000‡‡	
						Agricultural	55 tons			
Deer Pond	St. Lawrence	St. Lawrence	372	25	November 1977	Agricultural	12 tons	Boat	597	History of high use
Boottree Pond	St. Lawrence	St. Lawrence	374	20	November 1977	Agricultural	10 tons	Boat	502	History of high use
Buck Pond	Herkimer	Oswegatchie-Black	578	18	November 1977	Agricultural	9 tons	Boat	500	History of high use
Tamarack Lake	St. Lawrence	Racquette	171	13	February 1978	Agricultural	13 tons	Helicopter§	2,450	Preserve heritage strain of brook trout
Ice House Pond	Hamilton	Oswegatchie-Black	876	7	October 1978	Agricultural	7 tons	Boat	652	History of high use; natural brook trout spawning adequate
Brewer Lake	Herkimer	Oswegatchie-Black	967	13	November 1979	Agricultural	20 tons	Helicopter	2,550	Preserve heritage strain of brook trout
Livingston Pond	Essex	Upper Hudson	705	6	November 1979	Agricultural	6 tons	Helicopter	1,783	High use potential on major trail maintained by State

*As designated in "Biological Survey" of watershed as published by N.Y.S. Conservation Department.
§Spread on ice.
†Liquid.
‡Not complete.
‡‡Estimated.

The first and most straight forward method was simply to load bagged lime into a helicopter. Clear Lake was treated in this manner with hydrated lime in March 1975 (Table 1). The method was expensive, requiring a crew of eight men, but it was rejected as a viable method when a bag broke while the helicopter was operating and the interior of the aircraft was filled with a cloud of lime dust.

In the second method lime was loaded in a sling and transported by helicopter in 1-ton lots. In 1977, Clear Lake was retreated and Tamarack Lake was initially treated in this way, both with agricultural lime (Table 1). This method, too, was expensive and required considerable labor. A crew on the ice was needed to break open bags, spread the lime and gather and dispose of the bags. These first two methods were limited to winter as it was necessary for the helicopter to land for unloading at a pond. Also, winter operation in itself was a problem due to swirling snow which made flying difficult and extremely low temperature (often $-20°$ F.).

Ideally, lime should be spread directly by the helicopter (the third method), reducing crew size and allowing for year-around operation. This method was tried on Horn Lake and Falls Pond in November 1975 (Table 1). Hydrated lime mixed with an equal amount of water by weight was transported in a fire-fighting water bucket and spread directly on the lake surface as the helicopter flew slowly at an elevation of about 200 feet. The method proved too costly because, despite the lower amount of hydrated lime required, half of each load was water and the mixing required extra equipment and a crew of six.

While these experiments were taking place, the fourth method, dry dispersal, was being investigated. Commercial operators spreading fertilizer by helicopter were contacted and their methods evaluated. Ultimately, two lime "buckets" were purchased. Dispersal of lime by this method is straight forward. Two buckets are used, one on the ground being loaded while the second is transported to the pond by the helicopter. One-ton loads are normally carried. The helicopter moves over the pond at a moderate speed at an altitude of about 200 feet. A trap door is opened by the pilot and the load is dropped quickly (Figure 1).

To date, five ponds totalling 207 acres have been treated in this way. As with any new method, initial efforts involved additional costs in equipment and manpower. During the first trial in 1975, a bucket was inadvertently dropped and damaged. Then, in 1979, a bucket was accidentally dropped and damaged beyond repair. Thus, most work was done with a single bucket, which resulted in an inefficient operation.

Over-all, 12 ponds have been treated with agricultural limestone. Only three follow-up studies have been made (on ponds treated in 1977); all demonstrated improved pH values and excellent trout survival. Three ponds were barren prior to treatment, and it is planned to monitor them closely over the next several years to measure effects on water quality and survival of initial stockings.

Figure 1. Spreading dry lime on a remote pond from a bucket slung under a helicopter and (inset) loading a bucket with lime.

Recent reports, primarily from Scandanavia, have suggested that mobilization of mercury may cause increased levels in fish flesh following application of lime to acid ponds (Brosset et al., 1977). To ascertain if this phenomenon occurs in New York lakes, a study of mercury in brook trout from selected lakes, limed and unlimed, was undertaken in 1977 (Sloan et al., 1979). No increase in mercury levels was apparent in either limed or control waters. In fact, in one pond the levels in trout taken and analyzed prior to the initial liming were greater than those in fish taken in 1977 after liming.

Cost records were kept on 27 projects done in recent years. Because much of the effort was experimental, costs were probably higher than would be the case for "routine" projects. For example, assigning a crew to lime a series of accessible ponds without interruption results in maximum efficiency and lower costs. Liming four ponds in October 1977 by a three-man crew cost approximately $30 per acre. On the other hand, a single pond limed in 1978 cost $52 per acre.

Costs for liming remote ponds ranged as high as $297 per acre. However, it is felt that, on a routine basis, the average can be substantially reduced. Experience with the dry dispersal method has shown that lime can be moved at a rate of 5 tons per hour. At current rates, a helicopter

costs $250 per hour and a ground crew of eight men to load the buckets $35 per day each. Added to this is the cost of the lime, presently $40 per ton delivered to the site, and travel expenses to the site which vary depending on the job but are assumed to average $100 per day. Thus, the average cost should be about $100 per acre as follows;

Lime (1 ton)	$40
Helicopter	50
Labor	7
Other expenses	3

Benefits are based on angler use as derived from aerial censuses and the estimated value of an angler trip (Pfeiffer, 1979). Costs and benefits for six accessible ponds treated in 1977 and 1978, and for four remote ponds treated by the dry dispersal method in 1978 and 1979, are shown in Table 2. The assumed 3-year life of the treatments was based on prior exper-

TABLE 2. RELATION OF COST TO BENEFITS FOR ACCESSIBLE AND REMOTE PONDS IN NEW YORK THAT WERE LIMED TO ABATE ACIDITY

Item	Accessible ponds	Remote ponds
Ponds limed		
Number	6	4
Acres	196	97
Cost of liming		
Total	$10,456	$13,362
Per acre	53	138
Benefits		
Angler trips per year		
Total	3.528	388
Per acre	18	4
Valuation per year		
Per trip per acre*	$ 9.56	$ 10.51
Total per acre	172	42
Cost-benefit ratio§	1:9.7	1:0.9

*Derived from unpublished data furnished by M. H. Pheiffer.
§Based on expected 3-year life of treatment.

ience. This is likely a conservative estimate as most of that experience was with hydrated lime, and treatments with agricultural lime should be effective longer. Also, the cost-benefit ratios are based on treatments where the lime was applied at a maximum rate of 1 ton per acre. More recent data suggest that maintenance liming may require less than that for ponds with flushing rates of less than 90 per cent of their volume per year. Thus, the cost-benefit ratio for remote ponds would improve to 1:1.3 if the cost of $100 per acre for routine operations should be accurate.

It was concluded that, for both accessible and remote ponds, liming is an effective and economically feasible management tool which can be used

to counteract the adverse impact of acid precipitation and maintain selected fisheries.

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WEIGHT CHANGES IN REDHEADS AND CANVASBACKS DURING THE WINTER[1]

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ABSTRACT

Winter weights were recorded for 3,840 redheads and 1,272 canvasbacks live trapped on Seneca Lake, New York, during January, February and March from 1972 through 1976. Significant, progressive weight loss during this period was demonstrated for both species and within each species for both sexes of adult and immature birds. The greater metabolic demands of winter and limited plant-food resources probably accounted for the loss.

Migratory birds wintering at northern extremes of their winter range may be subject to rigorous environmental conditions. Weight change may be an indicator of the load the environment places on the metabolic systems of such birds. Data are presented here for two species of diving duck, i.e., the redhead (*Aythya americana*) and the canvasback (*Aythya valisneria*).

Most reports of body weight for these species do not apply to their northern range during the winter. Leopold (1919) recorded weights during the hunting seasons (fall and winter) of 1917 and 1918 in the Rio Grande Valley near Albuquerque, New Mexico. Weller (1957) recorded weights of redheads during the spring and summer on their breeding grounds. In other studies, weights for the two species were reported for the fall by Bellrose and Hawkins (1947) and for the summer by Longcore and Cornwell (1964).

However, Ryan (1972) recorded the body weights of over 1,200 diving ducks, mostly redheads and canvasbacks, in a part of their northern range, i.e., Seneca Lake, New York, during the winter. For both species, his data showed significant differences in weight in relation to age and sex: adult males being the heaviest, immature males being slightly heavier than adult females; and immature females being the lightest. Ryan also observed a general downward trend in body weight during the winter on this northern range, but the samples from the various groups were not large enough for judging significance. The ongoing waterfowl banding program on Seneca

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[1]A contribution of New York Federal Aid in Fish and Wildlife Restoration Project W-39-R. The authors appreciate the cooperation and support of Stephen Browne, Keith Mickel and Salvatore Cozzolino of the New York State Department of Environmental Conservation as well as the assistance of L. Koppelman, P. Cohen, S. Ryan and M. Ryan in operating the waterfowl banding station on Seneca Lake.

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Lake[3] afforded an opportunity to obtain additional data from the same area. Those collected from 1972 through 1976 are analyzed here.

METHODS

Waterfowl were trapped at Kashong Bay on the western shore of Seneca Lake 7 miles south of its northern end. Seneca Lake is the largest of the Finger Lakes and usually does not freeze over. Trapping was done each year during January, February and March. The traps used were similar to those described by Schierbaum and Talmage (1954), except that 1 x 1-inch wire mesh was used instead of 1 x 2-inch. Traps were placed in 2.5 to 3 feet of water and baited with corn or wheat, or both. Trapped birds were retrieved each day in the late morning and before dark and were recorded by date. Each bird was aged and sexed by cloacal examination as described by Hochbaum (1942). Weighing was done by placing the duck in a wire-mesh cone suspended from a Chatillon autopsy scale. Weights were recorded only for unbanded birds and for banded birds being handled for the first time that season. Weighing birds only the first time they were trapped avoided bias from repeated handling. The weight records were grouped according to age and sex.

The data were analyzed using a linear regression with more than one dependent variable for each independent variable. Time is the independent variable (X) and body weight the dependent variable (Y). More than one Y for each value of X is used, for there was no control over the number of birds of each group collected each day. The sample of birds taken each day ranged from 0 to 53 per group.

First in the treatment was an analysis of variance. Using this, the means from each day's sample can be analyzed. If the analysis of variance is not significant, it would indicate that the means are not significantly different from each other and that the body weights were similar from January through March. If the analysis of variance is significant, then the means are significantly different.

If the analysis of variance was significant, then a regression analysis was completed. That the analysis of variance was significant shows that a regression line might be fitted to the data. Computations for regression analysis were given by Sokal and Rohl (1969). The regression analysis is similar to an analysis of variance. However, the means are not being tested, but rather the slope of a regression line in relation to the individual data points. If the linear regression is not significant, then the slope of the regression line is equal to zero and no relationship between time and weight can be demonstrated. If the regression analysis is significant, then

[3]This program had been carried on since 1953 under the direction of the New York State Department of Environmental Conservation (formerly Conservation Department) and the U.S. Fish and Wildlife Service.

the slope of the regression line is greater than or less than zero and a relationship between time and weight can be inferred.

If a significant regression line was found, then its slope was calculated according to the computations of Sokal and Rohlf (1969). The regression is written in the form

$$Y = a + bx$$

where

Y = body weight
a = Y intercept
b = slope of regression line
x = time

Another test was made with the regression analysis, i.e., for the variability about the regression line. If the resulting value is not significant, there is explained deviation from the regression line, indicating that it explains much of the total variability. But if this value is significant, there is unexplained variability about the line. The trend of the regression line still holds true, but there is some factor or factors that cause variation about it.

RESULTS

The records for each species were divided into those for adult males, adult females, immature males and immature females. In each case the data for each year were analyzed separately to avoid masking the effect of changes in the environmental constraints on the birds. The results are shown in Table 1.

The indicated regression lines all have negative slopes, reflecting some degree of weight loss. For 13 of the 33 groups, analysis of variance showed no significant difference in body weight during the winter. However, in 11 of these cases, small samples may have accounted for the lack of significance. Nevertheless, for a majority of the groups weight loss over the study period was significant.

In Figures 1 and 2 the mean daily weights recorded for samples of the four age and sex groups of each species are plotted together with the associated regression line in each case. Ideally, it would be desirable for the samples for a given species to represent the same year so that all the birds would have been subjected to the same environmental conditions. However, the samples taken were not sufficient. For redheads, the best year was 1972, but the immature males were not adequately distributed over the winter period so those for 1976 were used. For canvasbacks, the best data involved three years; the records for immature females in 1976 were used instead of those for 1975 in order to compare data for adults and juveniles in the same year.

TABLE 1. ANALYSES OF BODY WEIGHT RECORDS FOR REDHEADS AND CANVASBACKS LIVE TRAPPED ON SENECA LAKE DURING THE WINTER, 1972-1976

Year	Age	Sex	Number of specimens	Equation for regression lines§	Significance of test†		
					1	2	3
			Redhead				
1972	Adult	Male	919	$Y = 1290.3 - 2.66x$	**	**	**
	Adult	Female	145	$Y = 1225.0 - 3.51x$	**	**	ns
	Immature	Male	223	$Y = 1175.7 - 1.40x$	ns		
	Immature	Female	109	$Y = 1137.2 - 2.58x$	**	**	**
1973	Adult	Male	558	$Y = 1262.4 - 2.57x$	**	**	**
	Adult	Female	131	$Y = 1149.8 - 1.85x$	**	**	**
	Immature	Male	171	$Y = 1191.1 - 2.12x$	**	**	ns
	Immature	Female	62	$Y = 1057.6 - 0.67x$	ns		
1974	Adult	Male	210	$Y = 1244.6 - 1.00x$	**	**	**
	Adult	Female	45	$Y = 1180.3 - 1.72x$	ns		
	Immature	Male	34	$Y = 1228.3 - 2.45x$	**	**	**
	Immature	Female	17	$Y = 1147.3 - 1.71x$	ns		
1975	Adult	Male	208	$Y = 1280.2 - 1.70x$	**	**	**
	Adult	Female	39	$Y = 1199.6 - 2.83x$	ns		
	Immature	Male	57	$Y = 1247.3 - 2.27x$	ns		
	Immature	Female	31	$Y = 1188.3 - 2.35x$	**	*	**
1976	Adult	Male	410	$Y = 1238.3 - 1.76x$	**	**	**
	Adult	Female	120	$Y = 1125.7 - 1.34x$	*	**	*
	Immature	Male	203	$Y = 1191.9 - 2.03x$	**	**	*
	Immature	Female	148	$Y = 1075.0 - 1.32x$	ns		
			Canvasback				
1972	Adult	Male	63	$Y = 1558.6 - 4.64x$	**	**	ns
	Immature	Male	43	$Y = 1408.1 - 3.15x$	ns		
	Immature	Female	29	$Y = 1303.4 - 2.80x$	ns		
1973	Adult	Male	48	$Y = 1405.8 - 1.17x$	ns		
1974	Adult	Male	71	$Y = 1351.0 - 0.45x$	ns		
1975	Adult	Male	181	$Y = 1452.2 - 1.42x$	*	*	ns
	Adult	Female	30	$Y = 1368.0 - 2.50x$	ns		
	Immature	Male	212	$Y = 1517.2 - 3.63x$	**	**	**
	Immature	Female	113	$Y = 1361.8 - 2.79x$	**	**	**
1976	Adult	Male	161	$Y = 1417.2 - 1.33x$	**	*	**
	Adult	Female	55	$Y = 1369.7 - 2.88x$	*	**	ns
	Immature	Male	63	$Y = 1361.1 - 1.83x$	ns		
	Immature	Female	68	$Y = 1313.9 - 2.93x$	*	**	ns

§See text for form of equation.
†Columns represent tests as described in text, i.e., 1 = analysis of variance, 2 = regression line analysis, and 3 = variability about regression line.
Significance denoted as:

*significant at 95 per cent level of confidence
**significant at 99 per cent level of confidence
ns not significant

The regression lines appear to be plotted too high for the means shown on each graph. However, they do not constitute analyses of the means plotted but of all the individual data points for each day calculated as a linear regression. To plot the individual data points would be impractical.

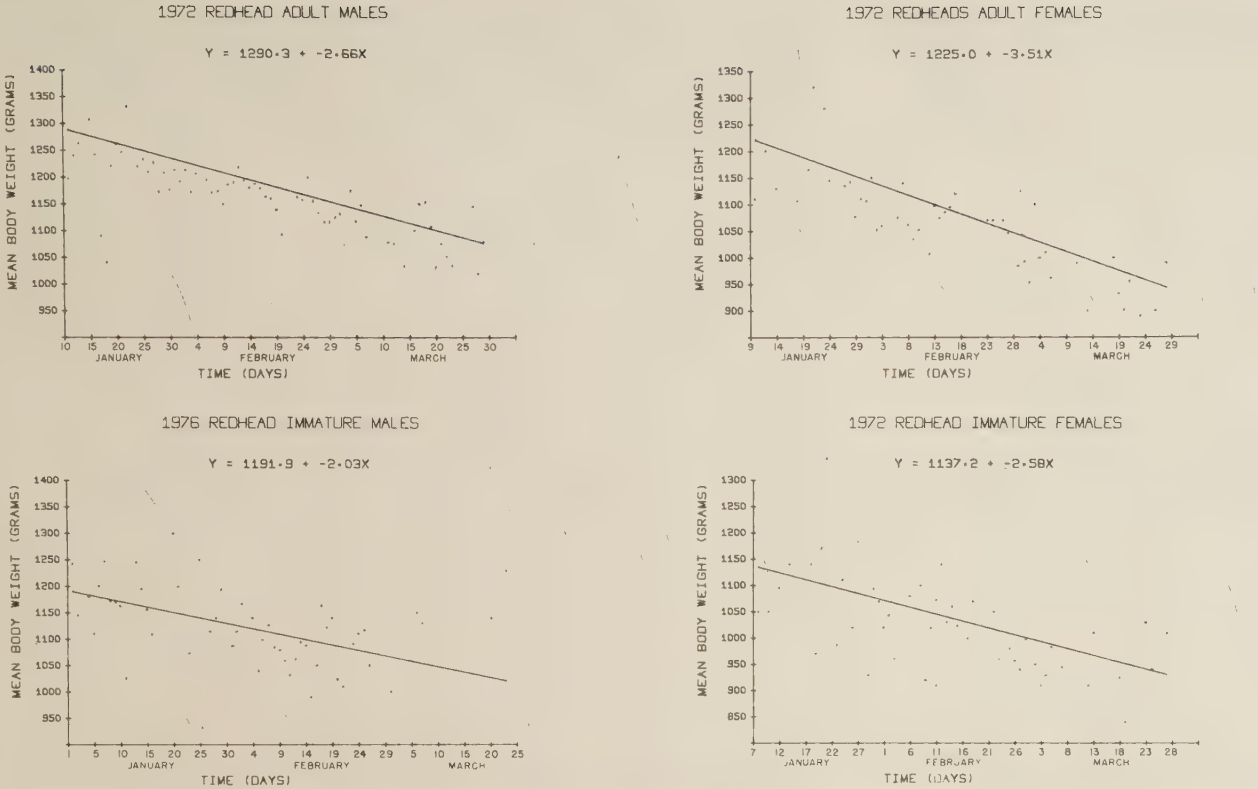

Figure 1. Relation of body weight to calendar date during the winter for redheads on Seneca Lake as indicated by daily means recorded and regression line representing individual data points.

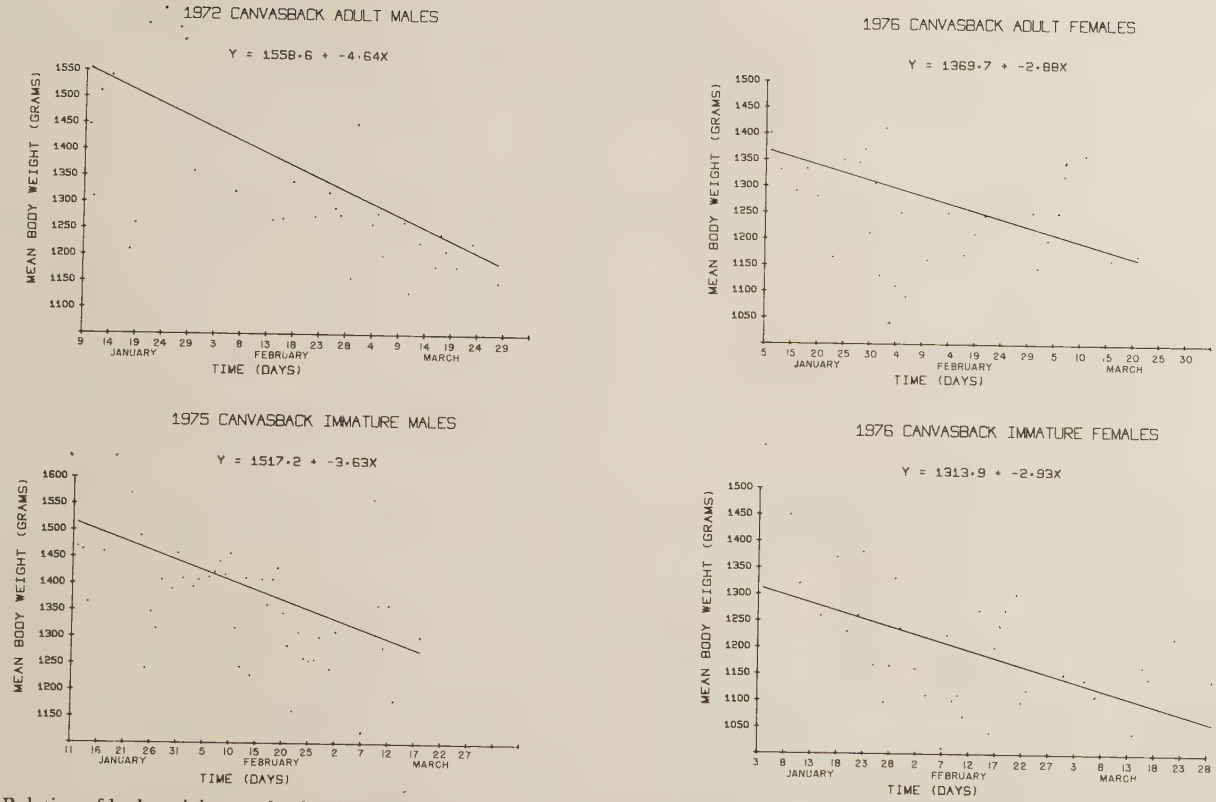

Figure 2. Relation of body weight to calendar date during the winter for canvasbacks on Seneca Lake as indicated by daily means recorded and regression line representing individual data points.

For redheads (Figure 1), the slopes of the regression lines for all the sex and age groups are negative and reflect a downward trend in body weight during the period.

The data for canvasbacks (Figure 2) show a similar downward trend in body weight, although the means are more scattered about the regression line. The highly variable size of the samples collected from day to day accounts for this scattering. The points which run askew are often for days when only one or two birds represented the population, but there is no way of controlling the number of birds entering the trap each day. However, the analysis was designed to take these unequal samples into account. The larger samples were given more weight than the smaller ones because they were better estimators of the population.

DISCUSSION AND CONCLUSION

The data show a significant, progressive loss of body weight in both redheads and canvasbacks during the winter (January through March) on Seneca Lake. Of the 33 sex and age groups analyzed, 20 showed this pattern. Of the 13 groups for which the tests were not significant, 11 were represented by small samples and therefore were poor estimators of the population as a whole.

Causes of the weight loss are probably numerous. As-yet-undetermined environmental conditions may prove the most significant. Waterfowl wintering at this northern extreme experience harsher conditions than those that move farther south in the Atlantic flyway. As temperature decreases, the metabolic rate increases (Gordon, 1972). Waterfowl in the more northern wintering areas have higher metabolic rates than those in southern areas because of the temperature differences. These birds must do additional metabolic work beyond the resting level to maintain a constant body temperature. Gordon (1972) suggested that birds in general cope with decreases in the environmental temperature by increasing their rate of metabolic heat production. As the metabolic rate increases, the energy input must also increase in order to maintain a constant body weight.

The data presented here show that, for both redheads and canvasbacks in the Seneca Lake wintering area, body weight decreased as the winter progressed. A possible reason for the decrease may have been a deficiency in usable foods that serve as sources of energy. The northern areas of the wintering range may not have adequate food supplies available to these species to enable the birds to maintain constant body weight when metabolic stress is present.

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AGING MALE RING-NECKED PHEASANTS BY BONE HISTOLOGY[1]

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ABSTRACT

Previous attempts to age game birds by using microscopic morphological changes in bones have been largely unsuccessful. This paper describes a new histological technique for separating juvenile from adult male ring-necked pheasants by using stained sections of the lower leg bone and toe.

In addition to banding, there are several methods of distinguishing immature from mature ring-necked pheasants (*Phasianus colchicus*) killed during the fall. These techniques include measurements of the bursa of Fabricius (Nelson, 1948; Harper et al., 1951; Stokes, 1954) and weights of the eye lens (Dahlgren et al., 1965). For males taken by hunters, biologists have generally found it most convenient to collect the scaled part of one leg and use the size, shape and color of the spur as the criterion of maturity (Kimball, 1944; Linduska, 1945; Stokes, 1957). The spur technique has seemed questionable, however, since Gates (1966) found that several experienced users of the method mis-aged 20 per cent of the adult and 1 per cent of the juvenile cock birds that they handled. Because a more precise and accurate method of aging pheasants (and other birds) was needed, a study was undertaken to determine if microscopic examination of the tarsal bones would reveal differences between juveniles and adults.

In previous morphological studies, Van Soest and Van Utrecht (1971) inferred that annual layers are deposited in the periosteal zone of birds. Klevezal et al. (1972) found layering in the periosteal zones of the humerus and zygomatic bones of 14 capercailies (*Tetro urogallus* and *T. parvirostris*) and one black grouse (*Lyrurus tetrix*), but they did not recommend general use of this technique until it was confirmed by adequate data from known-age birds. Schaaf (1979) concluded that counting the layers present in the periosteal zone of the phalanx and tarsometatarsus was not a suitable method for determining the age of mallard ducks (*Anas platyrhynchos*), but he urged further research on judging the age of birds by microscopic examination of the bones. Nelson and Bookout (1980)

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[1]The authors acknowledge the assistance of Donald Slingerland, conservation biologist of the N.Y.S. Department of Environmental Conservation, who did the photomicroscopy.

came to similar conclusions with respect to the Canada goose (*Branta canadensis*).

METHODS AND MATERIALS

Legs of wild male pheasants taken by hunters during the fall in the Ontario Lake Plain region of New York were used for the study. The specimens included 21 known-age birds (17 juveniles and 4 adults) that had been banded as nestlings or shortly thereafter. The juveniles ranged from 81 to 261 days old at death, while the adults were 18 months old. In addition, 52 specimens were of unknown age. The scaled part of one leg of each bird was collected and forwarded to the laboratory where age was first judged according to the spur technique by personnel of the Upland Game Bird Unit. The legs were then processed for microscopic examination.

Approximately 4-millimeter-thick segments of bone (with surrounding soft tissues attached) were cut from both the tarsometatarsus (proximal to the spur) and the third phalanx with a jeweler's saw. Such segments taken from dried leg bones do not require a fixative. The segments were decalcified in 40 per cent formic acid containing about 40 per cent ammonium polystyrene sulfonate (WIN-3000; Sterling Organics, New York) which generally took 1 to 2 days. Following decalcification, they were rinsed for an hour each in two changes of distilled water and stored in 70 per cent ethyl alcohol until sectioning. At sectioning, they were rinsed in distilled water and frozen at $-25\,^{\circ}$ C., after which transverse sections were cut at a thickness of 12 microns on a freezing microtome. The sections were placed on microscope slides and dried on a slide warmer for 24 hours.

For comparative purposes, sections from each bone were stained in Giemsa stain and Erhlich's hematoxlin. The Giemsa procedure consisted of staining the sections for 1 hour in a freshly made mixture of 20 milliliters of stock Giemsa stain in 500 milliliters of distilled water. Then the slides were rinsed in distilled water and dried on a slide warmer for 24 hours before being mounted with a coverslip in diaphane or being cleared in xylene and mounted in permount. The procedure used for Ehrlich's stain was that described by Schaaf (1979). The stained sections were examined with a light microscope (at magnifications of $40\times$, $100\times$ and $450\times$) using transmitted light. Most slide reading was done at $40\times$.

In addition, 3- to 5-millimeter-thick transverse segments were cut from the same bones of 30 of the 52 unknown-age pheasants and were cleaned of oils by rinsing in absolute ethyl alcohol. Each segment was placed in a cylindrical plastic mold and embedded in epoxy (Araldite; Ciba-Giegy Corp., Ardsley, N.Y.) with triethylenetetramine as the hardener. Once the epoxy was hard, the encapsulated bone's bottom face was polished on successively finer emery sheets using a standard two-speed polish grinder with a Whirlimet attachment. The polishing was finished by using a slurry of

gamma alumina in water on a kittenear cloth polishing lap. The embedded, polished segments were examined with incident illumination microscopy (Olympus MG inverted metallurgical microscope).

RESULTS

The bone segments embedded in epoxy were more difficult to interpret than the stained sections, but juveniles could generally be distinguished from adults. However, it was very easy to distinguish, from the stained sections of the lower leg bone and toe, the early-hatched from the late-hatched juvenile male pheasants, as well as juvenile males from adult males. Sections stained with Giemsa were far superior to those stained with Erhlich's stain. Sections of the tarsometatarsus and those of the phalanx were about equally easy to read under the microscope, but the phalanx bone was easier to section, place on slides and stain. Following are the key micromorphological characteritics for the three age groups as found in sections from these bones; for a given specimen, either bone may be used.

In the late-hatched juveniles (i.e., the youngest specimens), the periphery of the bone presents a very porous appearance (Figure 1), termed "Swiss cheese", and no clear periosteal zone has been formed. In general, the more "Swiss cheese" appearing in the periphery, the younger the bird. When stained in Giemsa, sections from birds of this group often tended to be bluer than those from older birds, probably reflecting the higher percentage of organic material in the less-ossified bone of young birds.

In the early-hatched juveniles (Figure 1), the periphery of the bone is far less porous appearing than in younger birds, and the bone is progressing toward having a developed periosteal zone. Figure 2 shows a section from an older juvenile that has a periosteal zone, and a few Haversian canals are present in the region but there is no adhesion line. The most difficulty in distinguishing juvenile from adult pheasant occurs at this stage.

With respect to adults, Figure 2 also shows a section from a known 18-month-old bird. It has well-developed endosteal, mesosteal and periosteal zones, and it has only small amounts of or completely lacks "Swiss cheese". There also is an adhesion line (cement line) present in the periosteal zone. Such lines occur in only part of the periosteal zone. Adhesion lines were not found in juvenile birds killed in October and November, but they are characteristic of adult males. The section shown in Figure 3 is believed to be from an older adult than the preceding one, and the bone is more ossified. Also, there are two adhesion lines present. The adhesion lines are difficult to perceive in the plastic mounts but are clear in the Giemsa-stained sections.

For the 52 unknown-age pheasants, there was good agreement (94.2 per cent) between the ages based on spur characteristics and those based on bone histology. In the microscopic examination of bone sections, one (3.4

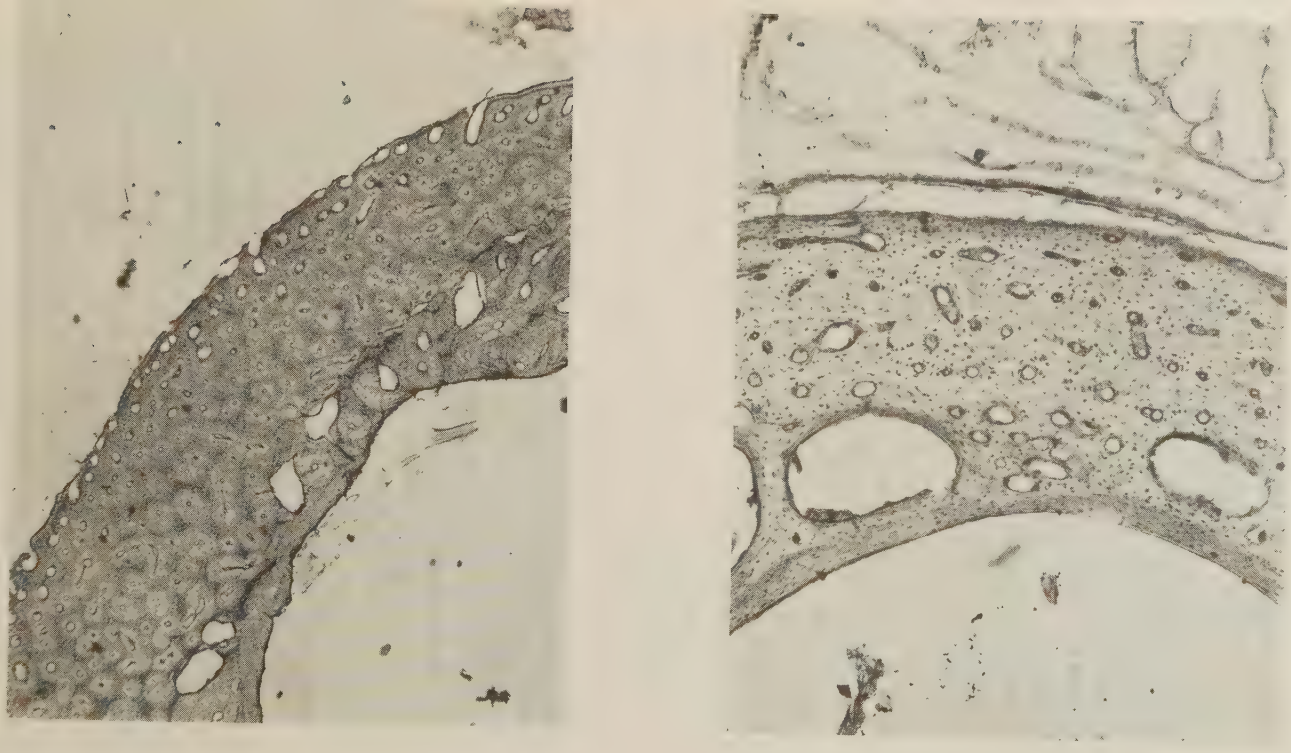

Figure 1. Transverse sections (left) of tarsometatarsus from a banded male pheasant killed during the hunting season at about 100 days of age and (right) of a phalanx from an older juvenile male (i.e., hatched earlier) showing less porosity. (approx. 40 ×)

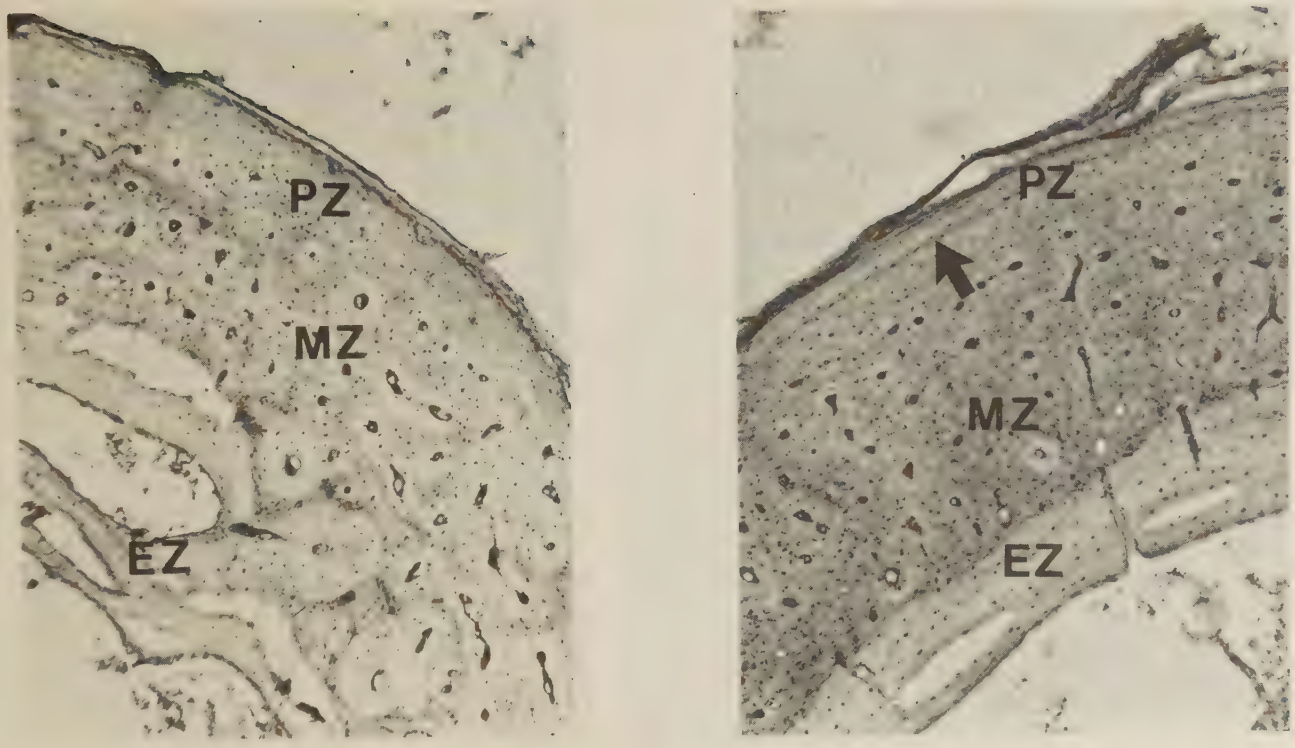

Figure 2. Transverse sections from (left) a male pheasant in transition from juvenile to adult and (right) a known-age (18-month-old) adult male, showing the periosteal zone (PZ), mesosteal zone (MZ) and endosteal zone (EZ). Arrow indicates adhesion line, but what appears to be an adhesion line in the periphery of the periosteal zone of the younger bird is periosteal membrane. (approx. 40 ×)

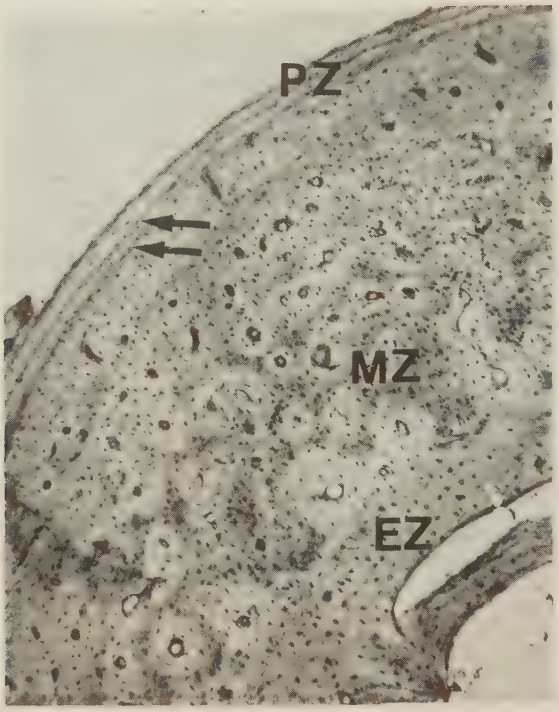

Figure 3. Transverse section of the phalanx from an adult male pheasant believed to have been older than 18 months, showing the periosteal zone (PZ), adhesion lines (arrows), mesosteal zone (MZ) and endosteal zone (EZ). (approx. 40 ×)

per cent) of the 29 specimens aged as juveniles was an adult, and two (8.7 per cent) of the 23 judged to be adults were found to be juveniles.

DISCUSSION

These observations indicate that the microscopic examination of thin sections from decalcified tarsometatarsal and phalanx bone, cut on a freezing microtome and stained with Giemsa stain, is a reliable method for determining the age of male pheasants. Since it enables the differentiation of late-hatched birds from early-hatched birds (i.e., from first nestings), it could be of special use to biologists when widespread failure (e.g., from weather, predation or other causes) of first nestings is suspected. With respect to adults, however, data are needed for known-age males to determine how definitively the age of such birds can be judged as they grow older. The method may also be applied to random samples of pheasants aged by the spur method as a check on accuracy.

For bones too fragile for decalcification or those that stain poorly when decalcified (e.g., bones from an archaeological context or from a deter-

iorated specimen), the epoxy technique may be useful. Also, it could be used when no freezing microtome is available.

With respect to the interpretation of stained sections, there also may be significant differences, associated with the strain of pheasant, nutrition and geographic location, in the timing of morphological changes in the bone. Furthermore, the characteristics of sections of bone from female pheasants may differ considerably from those of sections from males because of resorption of bone to supply calcium for egg shells (Urist and Deutsch, 1960). How the method may apply to other bones of the pheasant or to bone of other species is not known. Nevertheless, where facilities for using it are available, the authors consider this technique the best choice for aging male ring-necked pheasant.

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